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DOT HS-805-200

UNDERRIDE GUARD DESIGN FEASIBILITY STUDY

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The Budd Company
Technical Center
375 Commerce Drive
Fort Washington, Pennsylvania 19034

Contract No. DOT HS-9-02289
Contract Amt. $16,000

NOVEMBER 1979
FINAL REPORT

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Prepared For
U.S. DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
Washington, D.C. 20590

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT HS-805 200		

4. Title and Subtitle	5. Report Date
Underride Guard Design Feasibility Study	November 1979
	6. Performing Organization Code
	8. Performing Organization Report No.
7. Author(s)	TCR-0584-1
G. P. McCafferty	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
The Budd Company Technical Center 375 Commerce Drive Fort Washington, PA 19034	11. Contract or Grant No. DOT HS-9-02289
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	Final Report October to November 1979
U.S. Department of Transportation National Highway Traffic Safety Admin. Washington, D.C. 20590	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

A parametric design analysis was performed in order to define the characteristics of protection devices which could be incorporated on the rear end of highway trailers in order to avoid automobile vehicle underride in a crash situation. Of particular concern in this study was the effect of weight and cost of the devices as they relate to parameters such as load capacity, guard height, restriction of the rear sliding bogie movement, and energy attenuation. Four separate design concepts were developed and compared on the basis of weight, cost, and slider restriction. Included were rigid as well as energy absorbing design approaches. Results have generally indicated that the energy absorbing guard approach has the best potential from a weight efficiency standpoint. The study also points out that significant modifications will be required to the trailer structure to absorb the impact loads under consideration.

17. Key Words	18. Distribution Statement
Trailer Safety Vehicle Crashworthiness Vehicle Underride Trailer Bumper Guards	Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	60	

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METRIC CONVERSION FACTORS

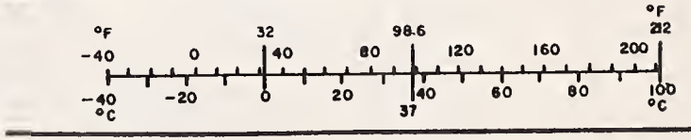
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	squere miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	squere miles	mi^2
ha	hectares (10.000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit tempereture	°F



PREFACE

The assistance and contributions of Mr. John Chionchio, Mr. Richard Marvin and Mr. Doug Poindexter of The Budd Company in the completion of this project and report are appreciated.

The guidance and assistance of Mr. John Tomassoni and Mr. Gary Bell of the National Highway Traffic Safety Administration are also appreciated.

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1.0 INTRODUCTION

The design study work described herein was performed by The Budd Company Technical Center in support of the U.S. Department of Transportation, National Highway Traffic Safety Administration under Contract No. DOT-HS-9-02289.

The basic problem being addressed by this report is that of the automobile collision into the rear end of a highway trailer and resultant underride of the automobile structure. The specific objective of this project was to perform a parametric design analysis to establish the characteristics of a variety of rear-end protection devices.

Of particular concern in the design analysis was the degree of restriction the rear-end protection devices might cause in the rearward positioning of the sliding bogie. Due to the potential loss in revenues associated with the reduced load capacity by restricting bogie position, this study has considered mainly design concepts which would not interfere with the bogie placement.

Four separate design concepts were developed and analyzed for comparison of weight and cost implications. The weight and cost of these approaches were further varied as a function of parameters such as crash load capacity, guard height, and degree of bogie restriction.

The results of this parametric study are given on the pages following in Section 2.0 of this report.

Two appendices are attached to this report. Appendix 'A' gives a detailed tabulation of weight results by category and Appendix 'B' is a background narrative on scale model testing as recommended herein.

2.0 RESULTS

The four design approaches selected for evaluation were:

1.) a rigid vertical guard suspended from the rear frame of the trailer,

2.) a rigid guard with rear struts suspended by the longitudinal slider support beams with and without bogie interference,

3.) a rigid guard supported with struts outboard of the slider beams, and

4.) an energy absorbing guard mounted to the rear frame.

The results are given for each category of design approach.

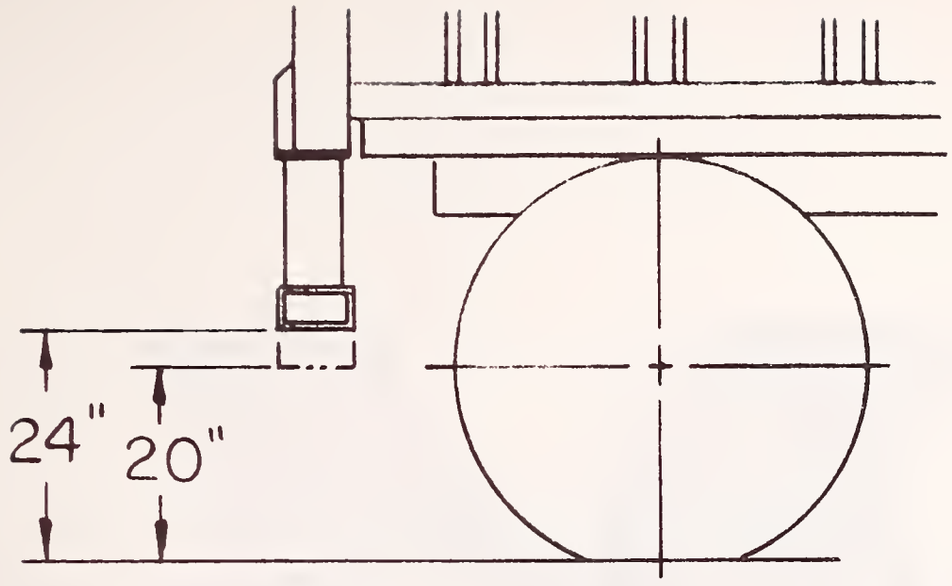
The loading conditions and guard height conditions which were used for the analysis per the work statement are shown in Figure 2-1. As illustrated, the centric loads were applied over a 27 inch span and the offset over a 13 1/2 inch span.

In considering the weight/cost characteristics of the various guard configurations, it is necessary to take into account the ability of the current trailer structure to absorb the load inputs from the guard devices. We have, therefore, attempted, within the limited scope and timing of this study, to identify where additional weight for structural modifications will be required. It is not possible, however, or prudent to attempt within this study to accurately definitize such things as the exact magnitude of these changes on the multiplicity of trailer structures currently in production.

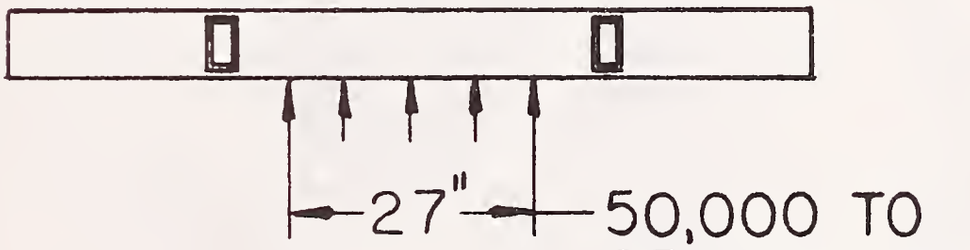
A considerably more detailed study would be required as discussed in our recommendations herein.

2.1 Rigid Vertical Guard

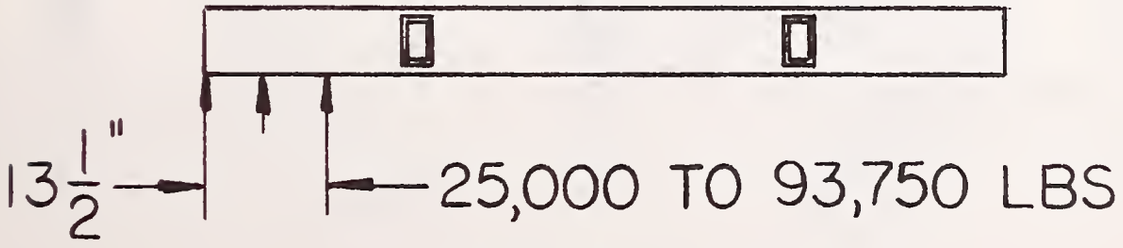
Our initial design with the straight vertical guard employed standard commercially available box sections which were sized to meet the loading criteria mentioned above. These concepts are illustrated in Figures 2-3 and 2-4. The configurations shown in the figures represent designs which will meet centric loading conditions of 50,000 lbs. and 125,000 lbs., respectively. For comparison, our currently produced underride guard is shown in Figure 2-2 and, when judged by the same loading criteria, is capable of withstanding approximately 25,000 lbs. prior to yielding.



GUARD HEIGHT



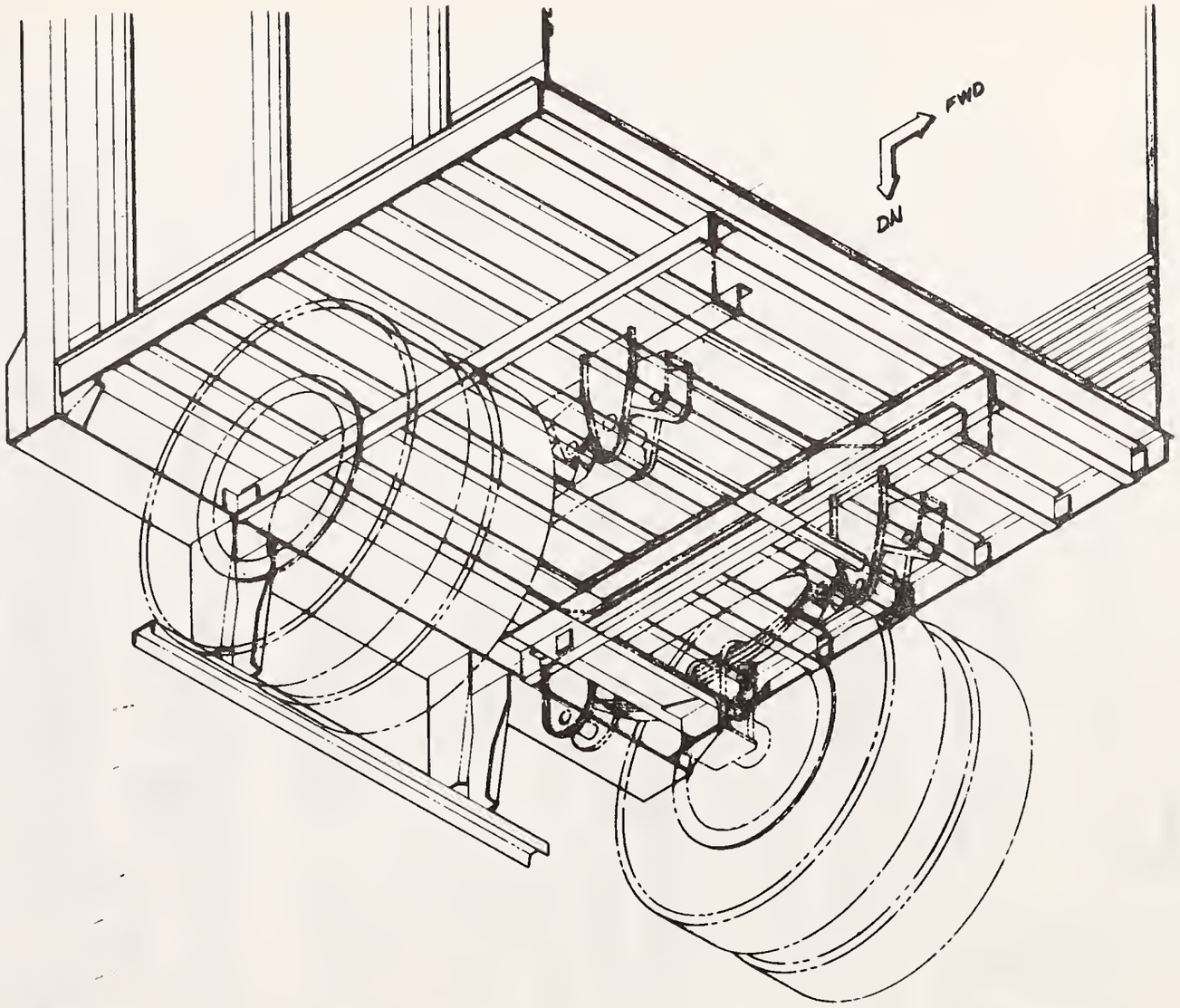
CENTRIC LOAD



OFFSET LOAD

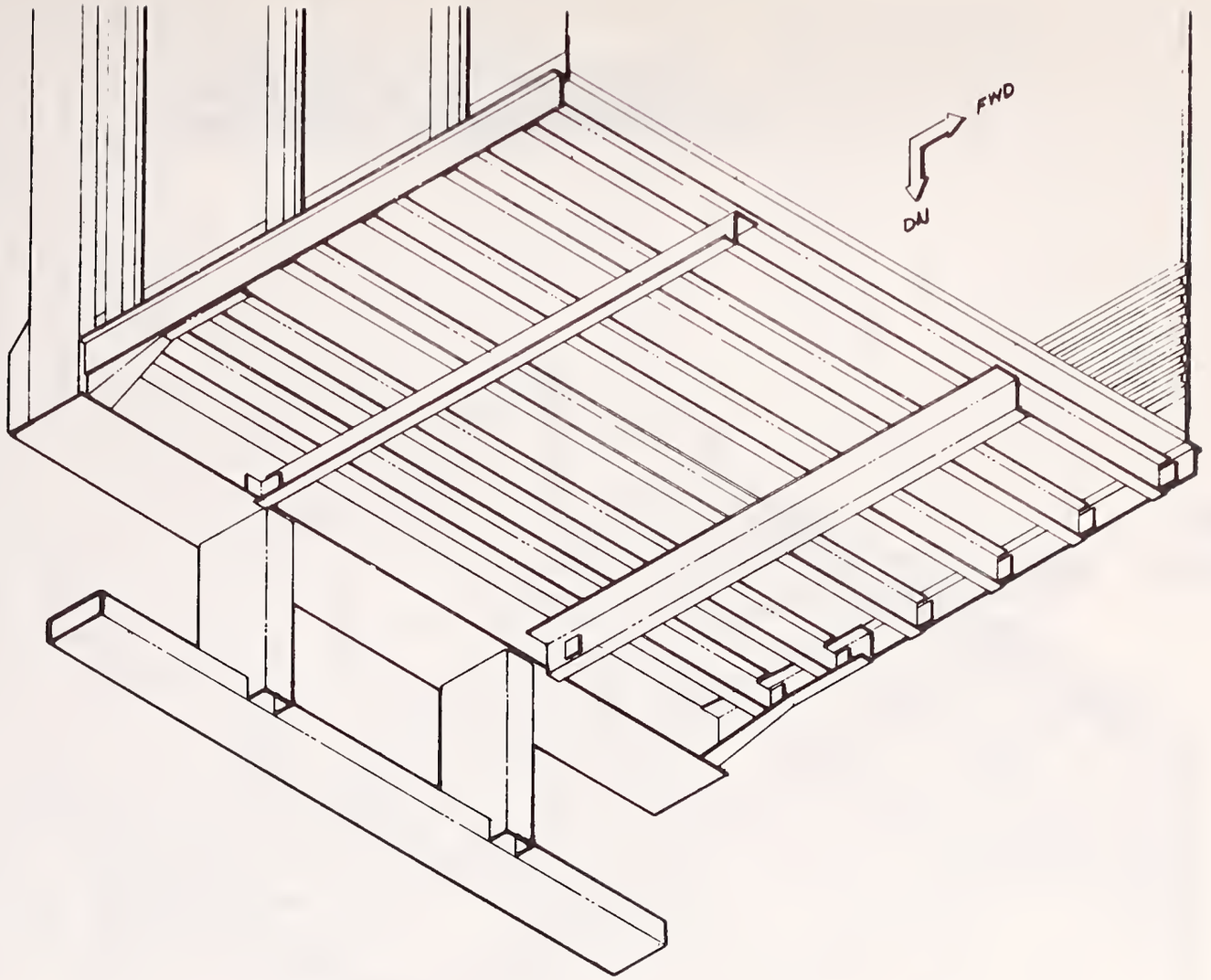
DESIGN CRITERIA

FIGURE 2-1



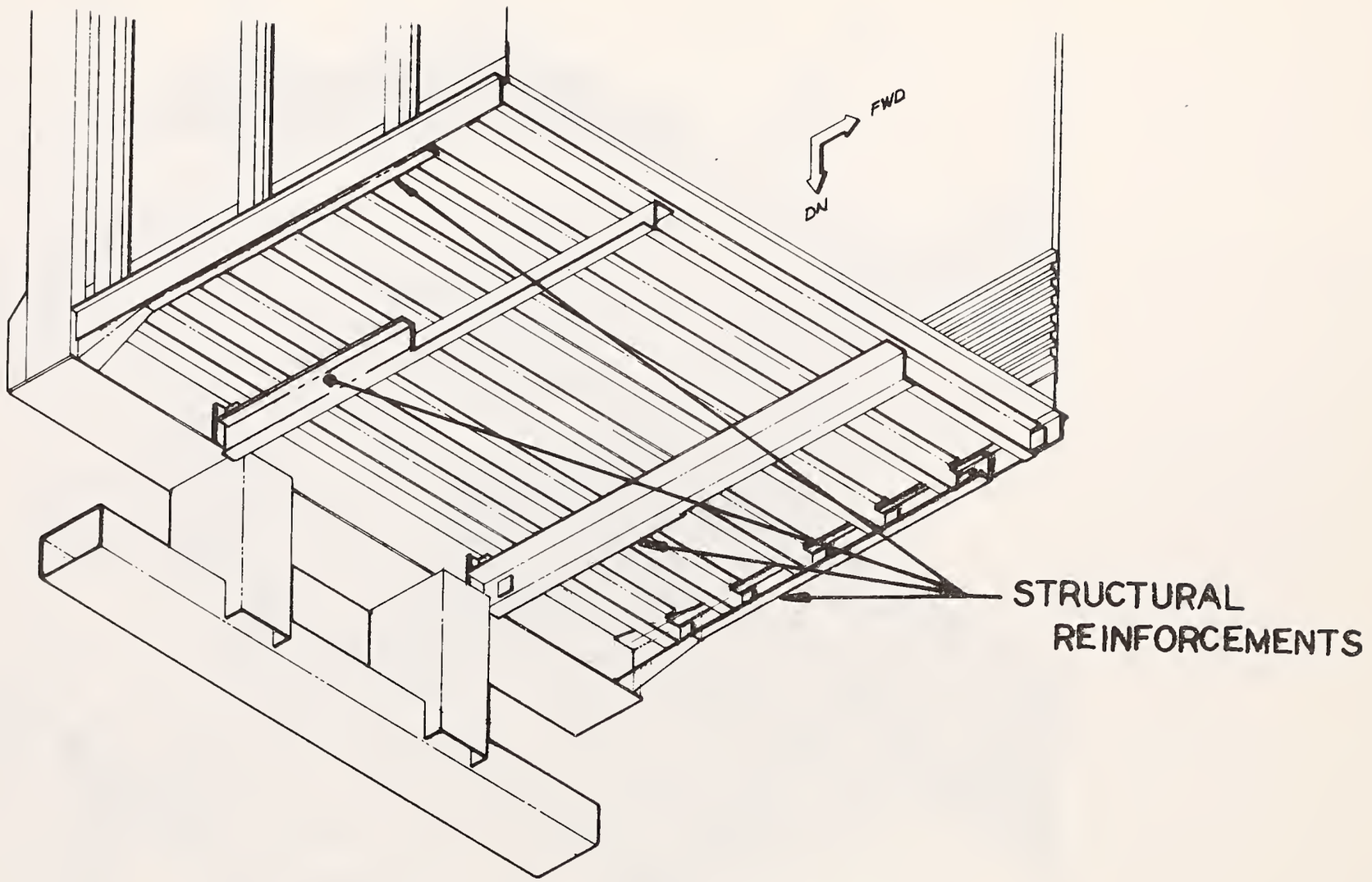
EXISTING
UNDERRIDE GUARD CONFIGURATION

FIGURE 2-2



RIGID VERTICAL GUARD CONFIGURATION
50,000 LB CENTRIC LOAD DESIGN

FIGURE 2-3



RIGID VERTICAL GUARD CONFIGURATION
125,000 LB CENTRIC LOAD DESIGN

FIGURE 2-4

As illustrated in Figure 2-4, additional structural reinforcements in the rear sill, lower side rail attachment area, and the sliding rail attachments are judged to be required in order to react the moments imposed by the higher loading conditions.

Configurations were sized for each of the design conditions. A detailed tabulation of results is given in Appendix 'A'.

The overall weight/fabrication cost results for the vertical rigid guard configurations are given in Figure 2-5. Plotted on the abscissa is weight in pounds which can be converted to cost since our estimate for this type of construction is approximately one dollar per pound. The weight or cost is plotted as illustrated as a function of guard height and is given for each of the centric loading conditions.

The results for the offset loading condition with the rigid vertical guard are given in Figures 2-6 and 2-7. Figures 2-6 and 2-7 represent the fifty percent and seventy-five percent of centric loading conditions, respectively. The offset loads represent a much more severe criteria as illustrated by the added weight shown in comparison to the centric load data.

It should be noted that up to approximately thirty-five percent of the weight shown can be attributed to additional structural modifications. For example, in Figure 2-7, with the maximum loading of 93,750 lbs. with 20 inch height, approximately 400 pounds are required for the device and the remaining weight (approximately 160 lbs.) are added structure. In an attempt to minimize the guard device weight, other sections were analyzed for comparison to the box-beam configuration in a straight vertical guard. Some slight efficiencies were realized as expected by utilizing an I-beam section for the horizontal beam as illustrated in Figures 2-8 and 2-9. These represent the 50,000 lb. and 125,000 lb. loading equivalents of Figures 2-3 and 2-4 previously discussed. The resultant weight effects are seen in the graphs of Figures 2-10 through 2-12 representing the centric and offset loading conditions.

RIGID VERTICAL GUARD WEIGHT VRS HEIGHT
CENTRIC LOAD (BOX BEAM)

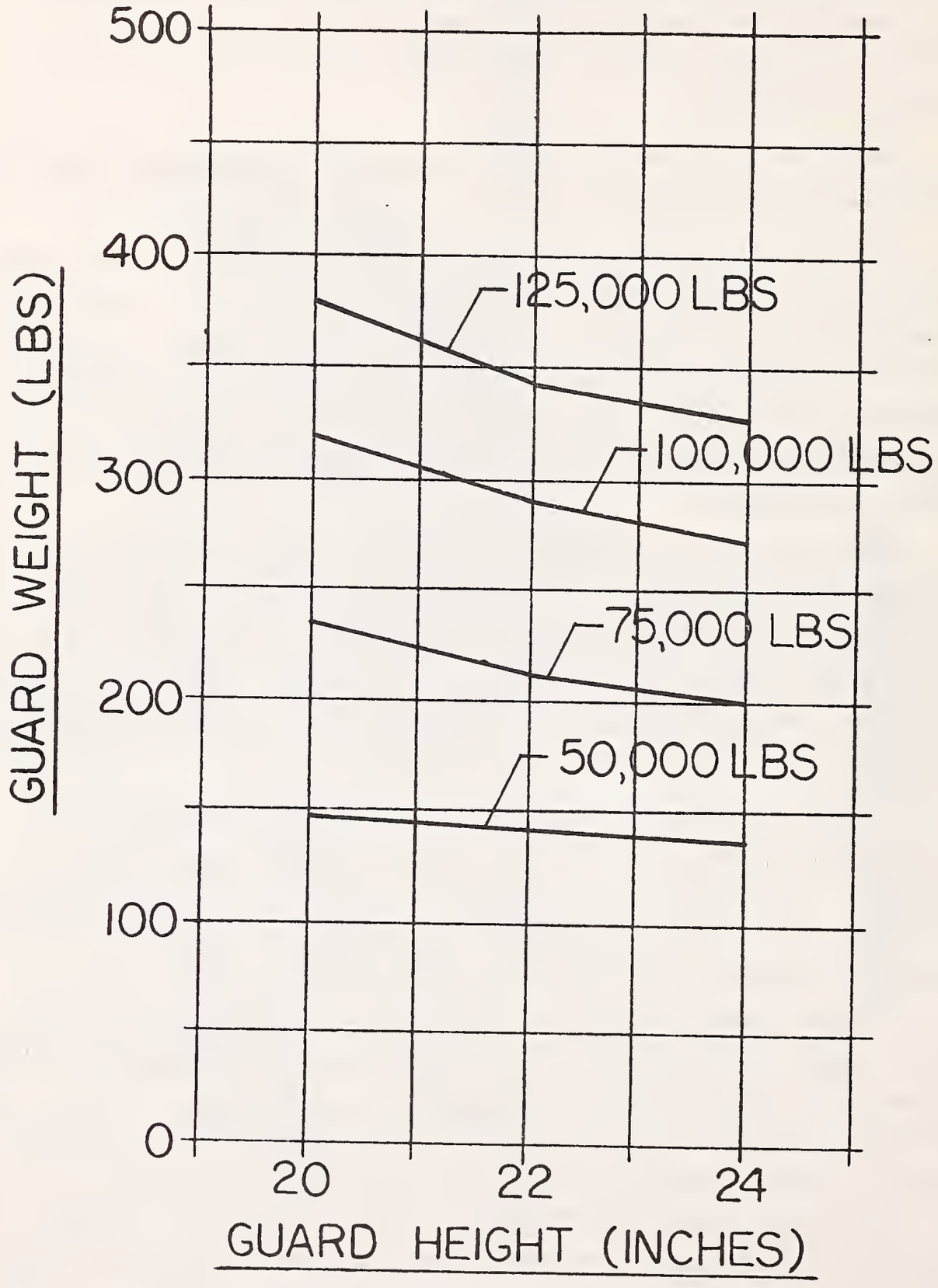


FIGURE 2-5

RIGID VERTICAL GUARD WEIGHT VRS HEIGHT

50% OFFSET (BOX BEAM)

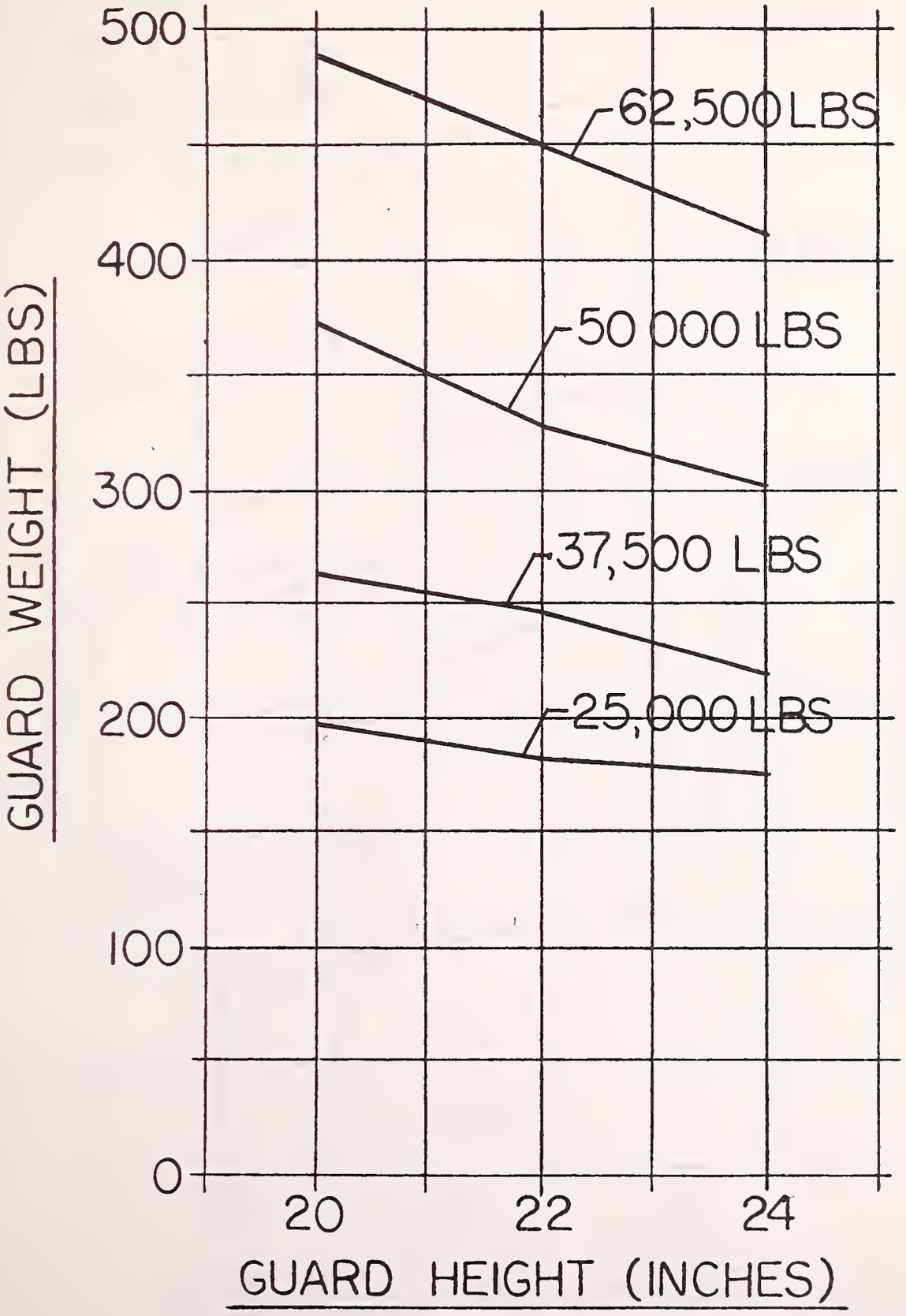


FIGURE 2-6

RIGID VERTICAL GUARD WEIGHT VRS HEIGHT
75% OFFSET (BOX BEAM)

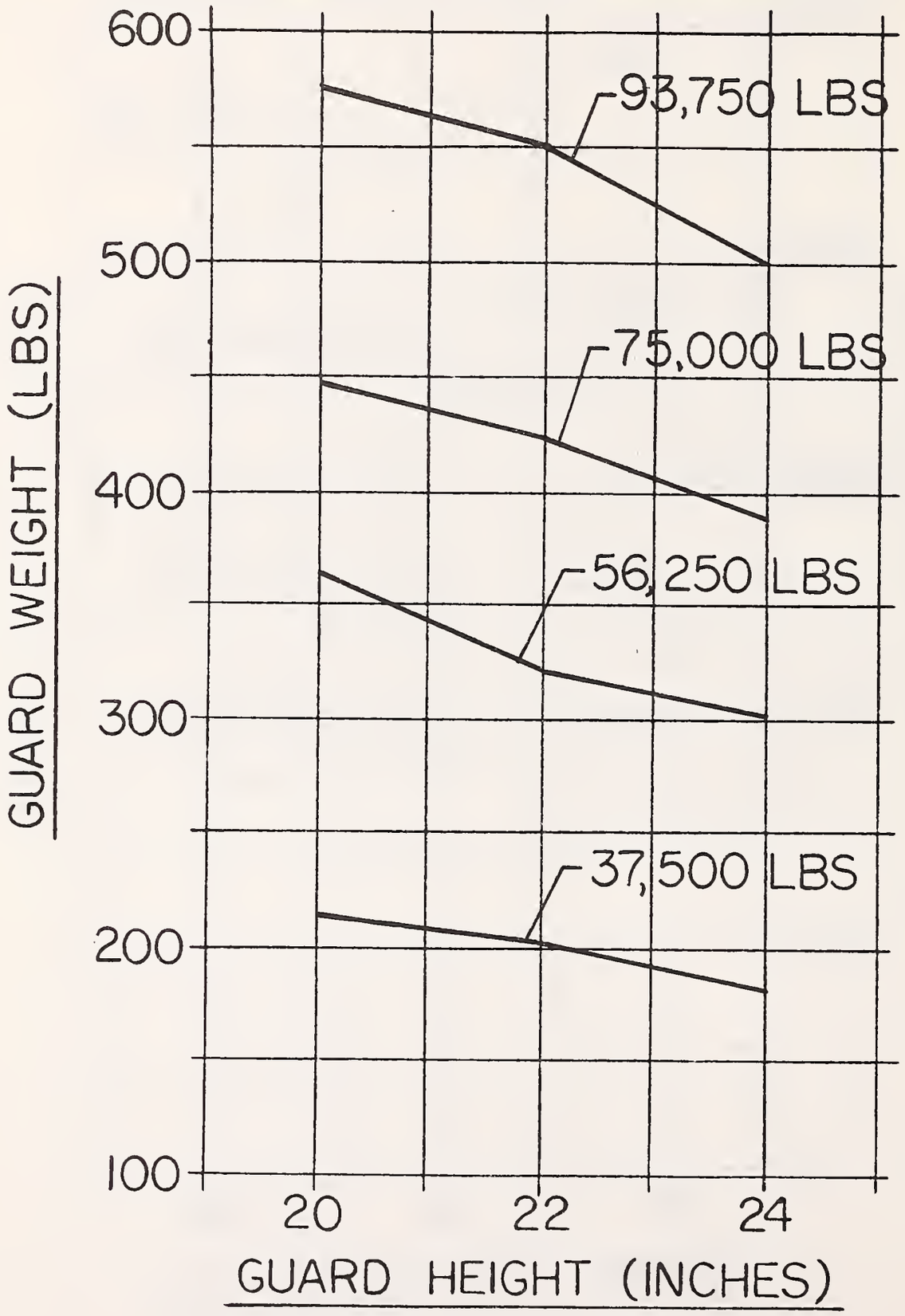
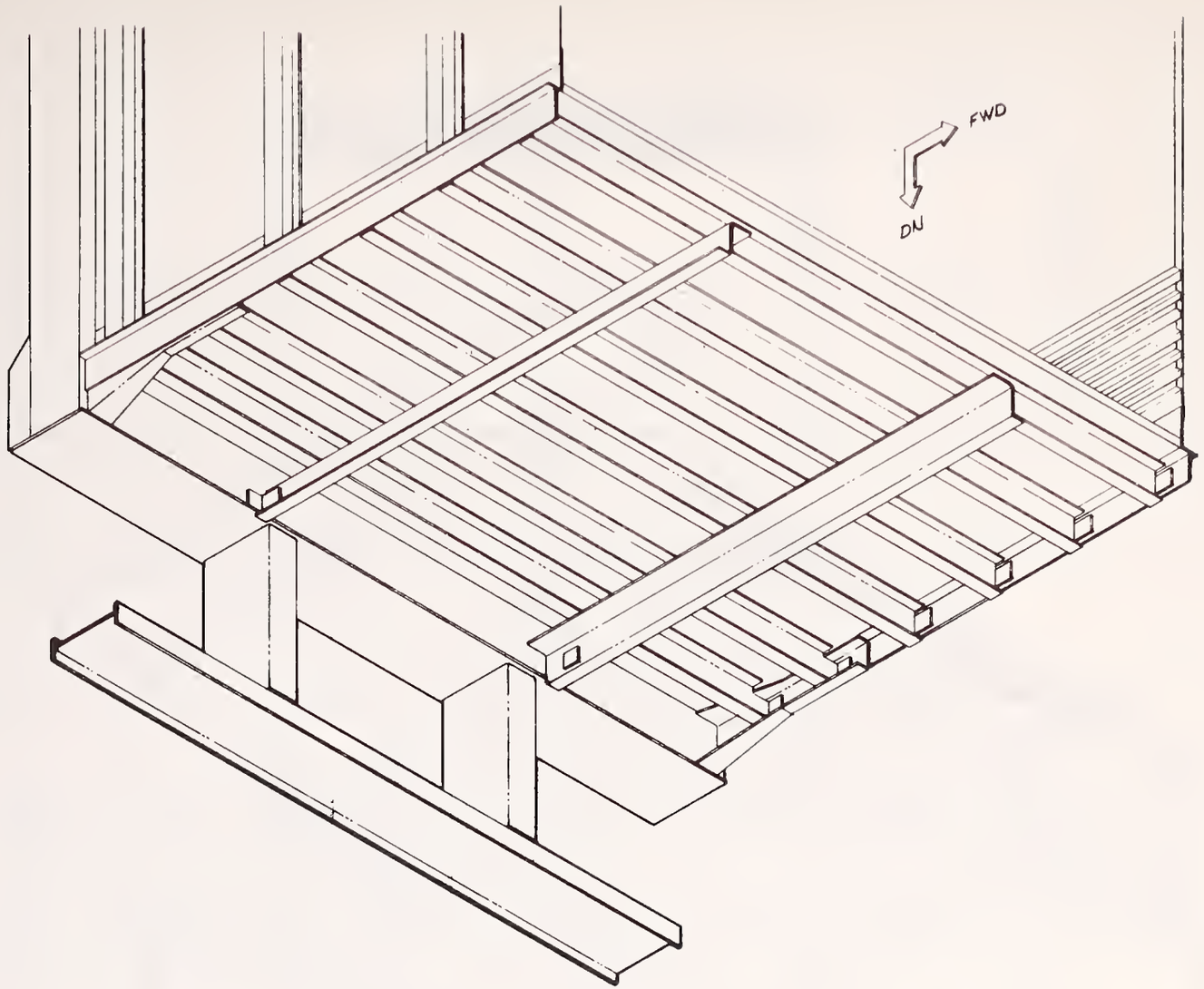
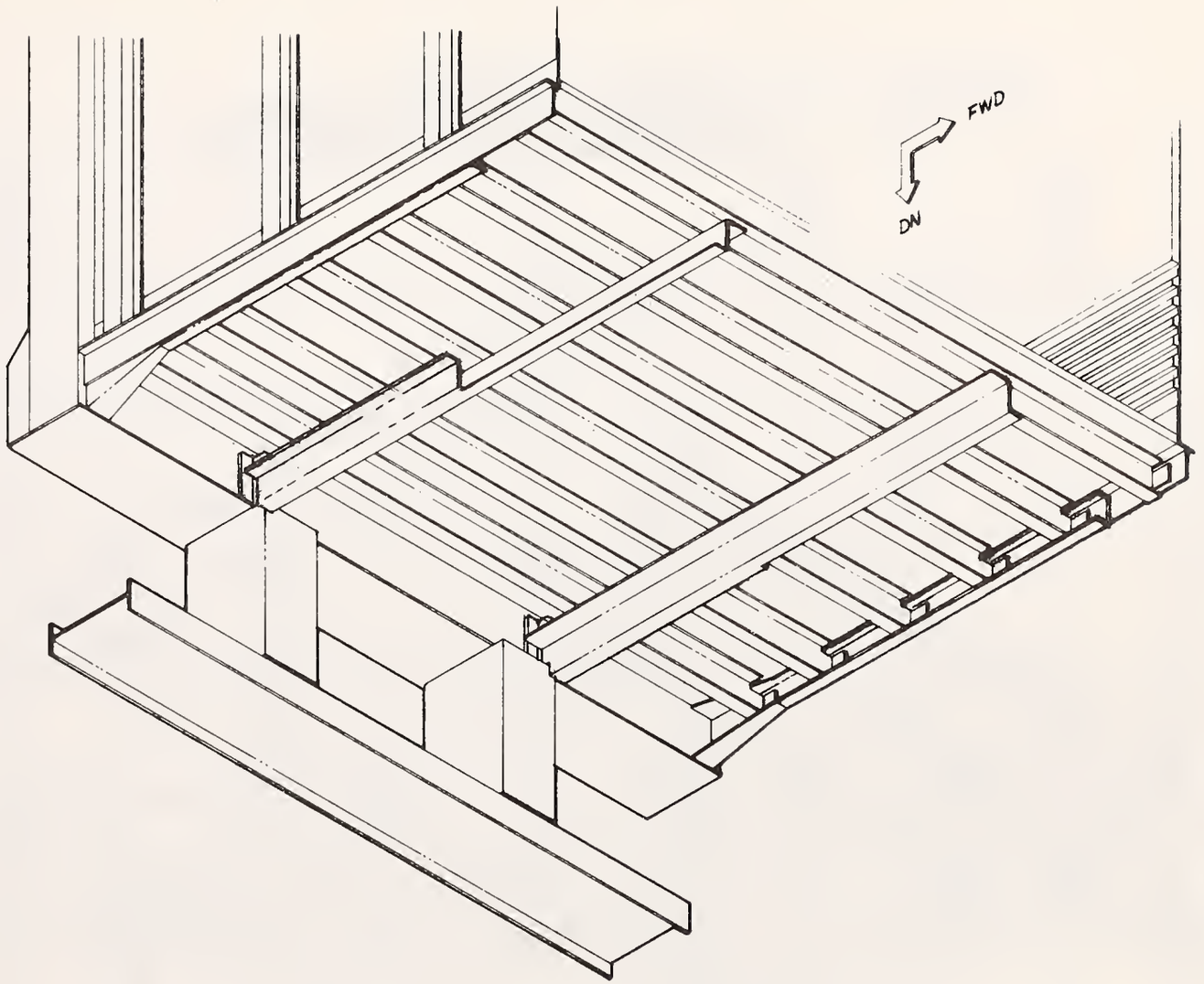


FIGURE 2-7



RIGID VERTICAL GUARD CONFIGURATION
50,000 LB CENTRIC LOAD DESIGN

FIGURE 2-8



RIGID VERTICAL GUARD CONFIGURATION
125,000 LB CENTRIC LOAD DESIGN

FIGURE 2-9

RIGID VERTICAL GUARD WEIGHT VRS HEIGHT
CENTRIC LOAD (I BEAM)

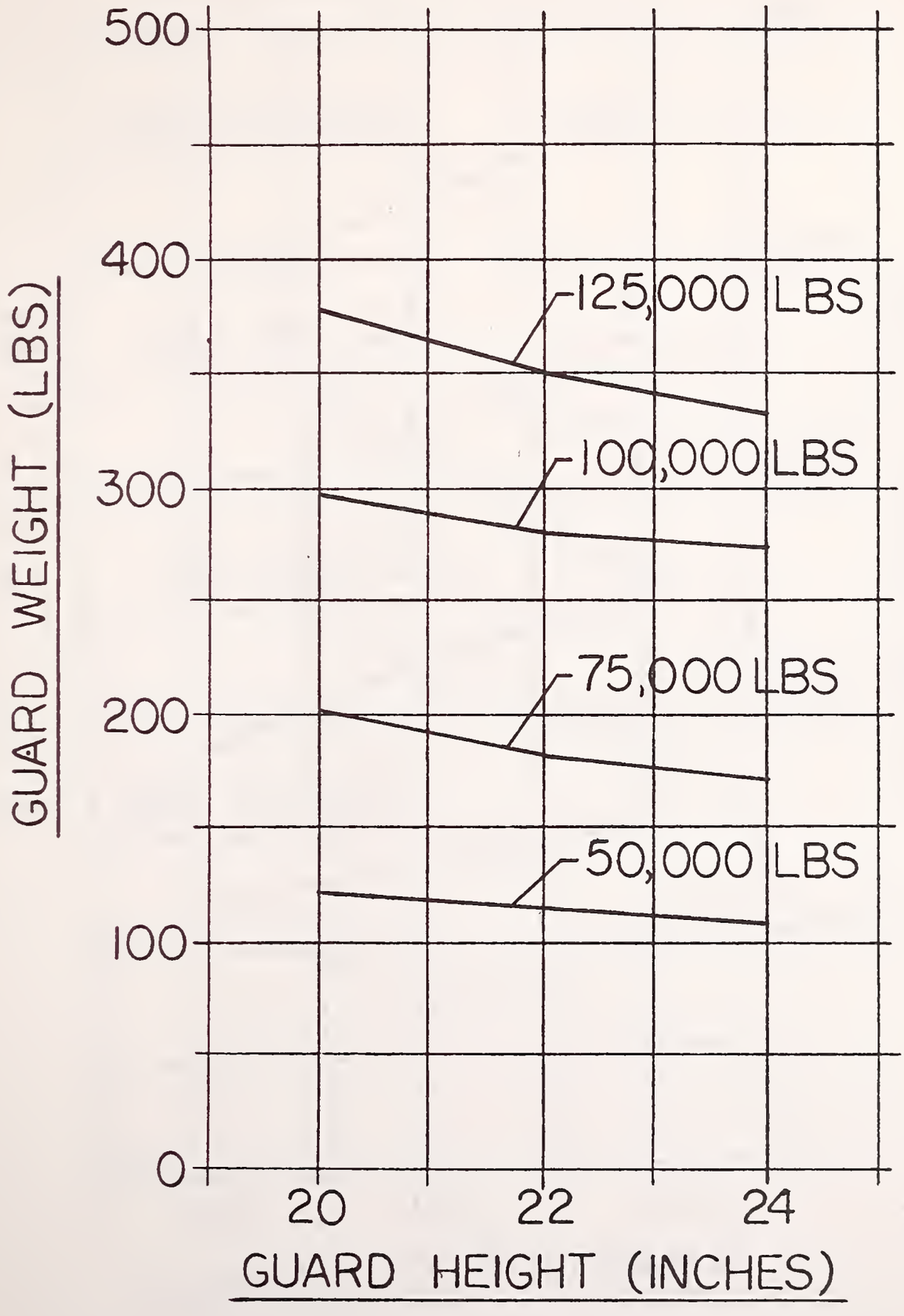


FIGURE 2-10

RIGID VERTICAL GUARD WEIGHT VRS HEIGHT
50% OFFSET (I BEAM)

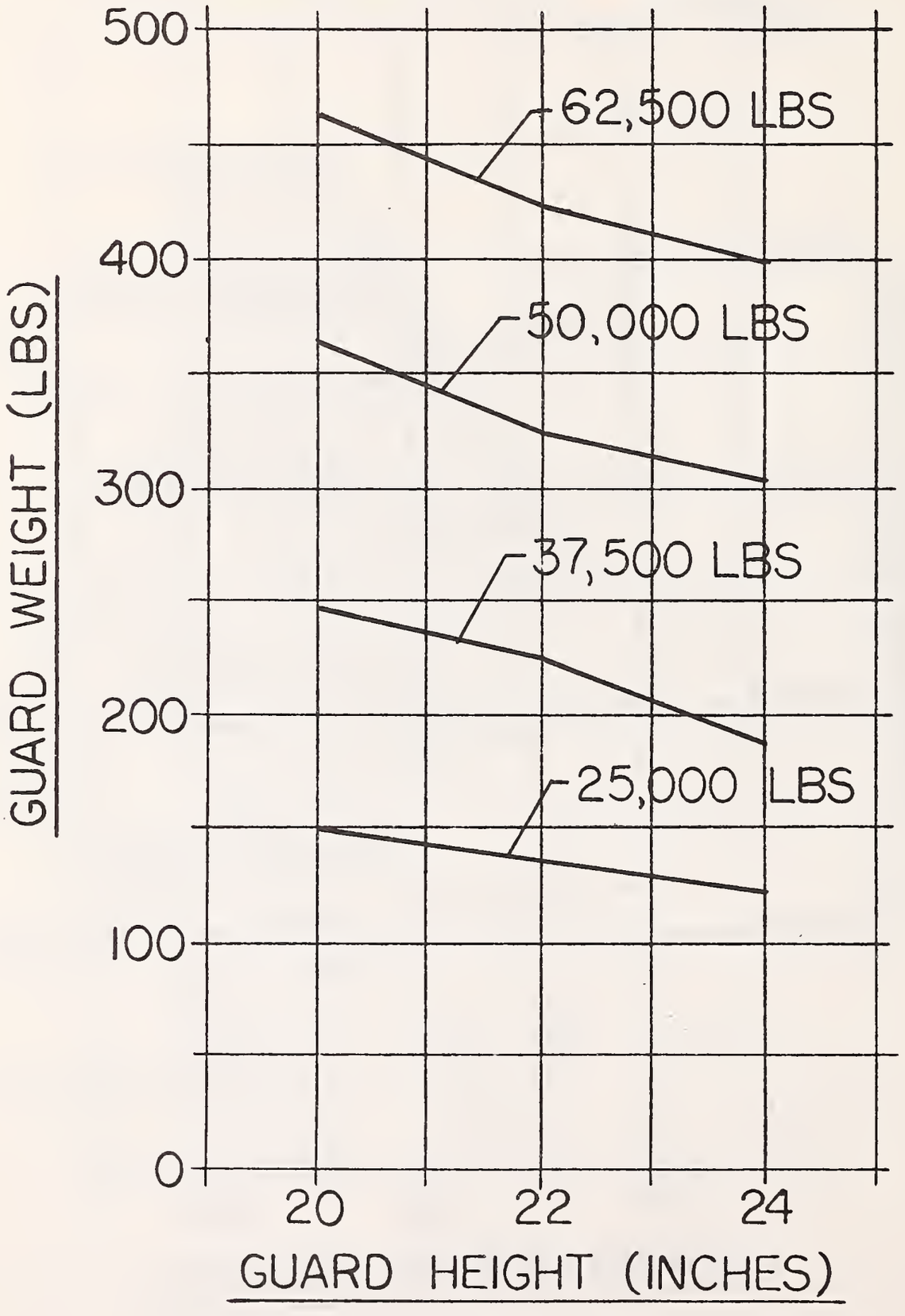


FIGURE 2-11

RIGID VERTICAL GUARD WEIGHT VRS HEIGHT

75% OFFSET (I BEAM)

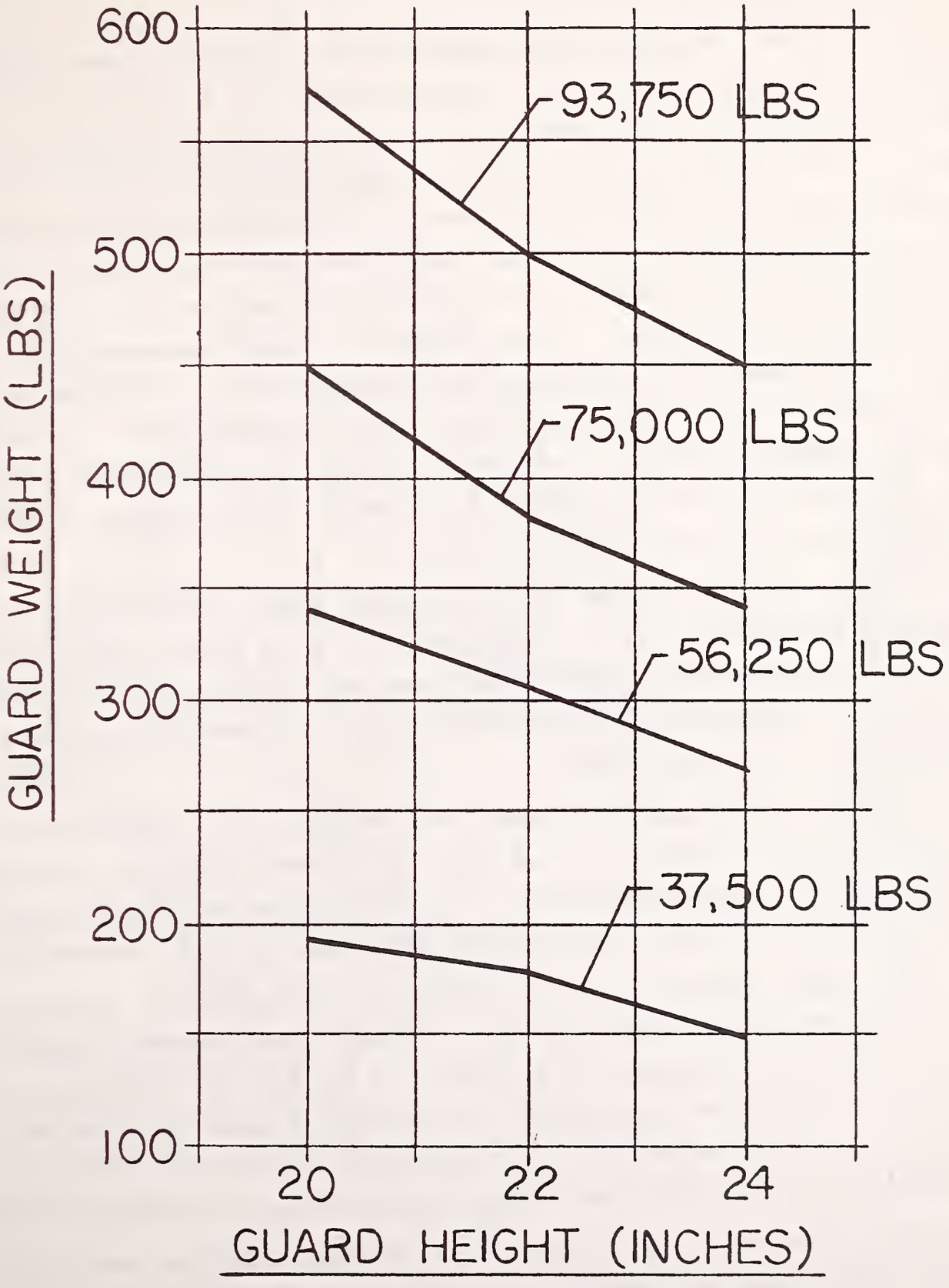


FIGURE 2-12

This data indicates a slight reduction in weight over the box configuration.

2.2 Rigid Guard-Strut Supported

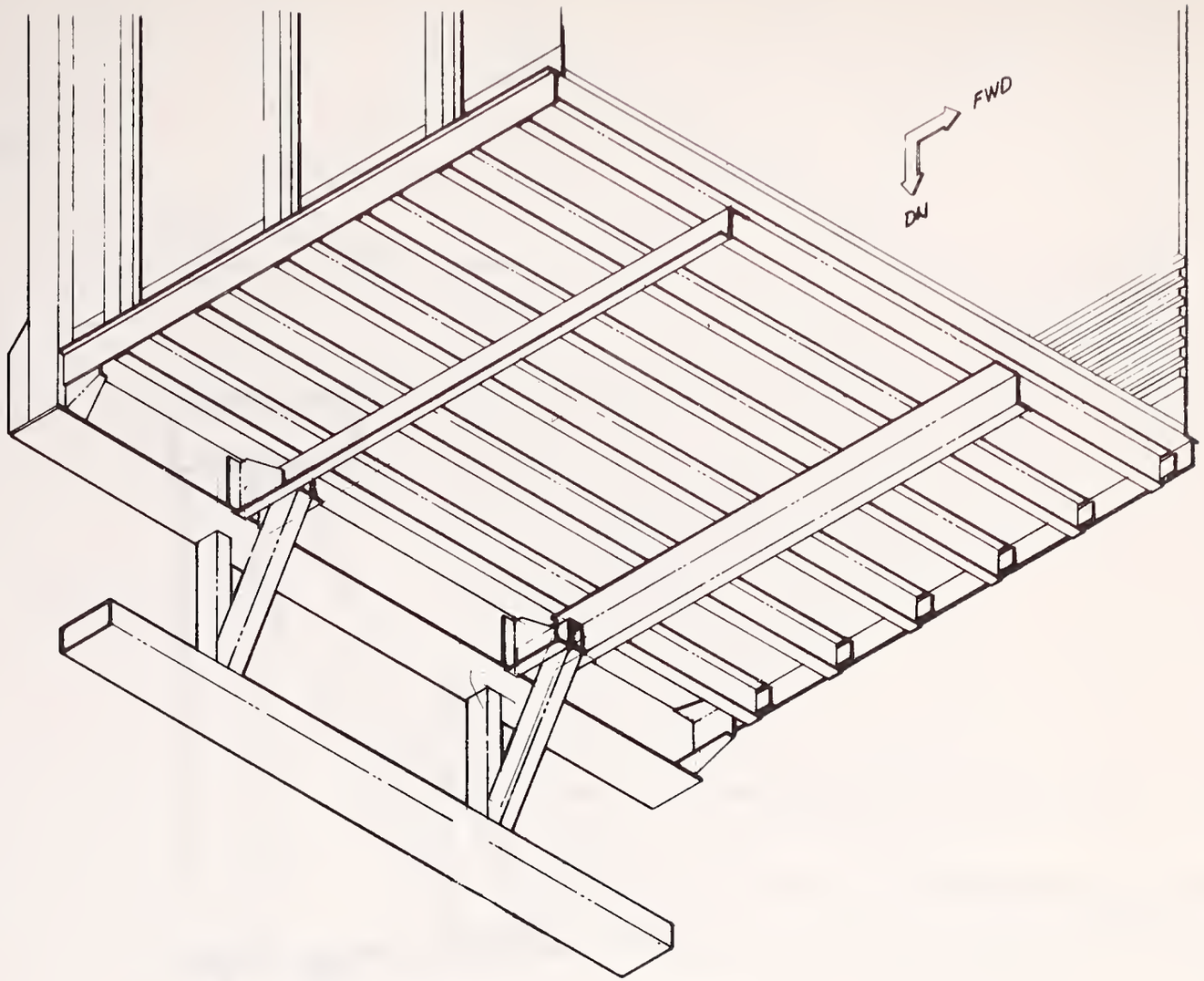
The second configuration analyzed was that of a rear strut support guard with that strut transmitting load back to the sliding bogie rail member. This approach is illustrated in Figure 2-13 which is the configuration sized to meet the 50,000 lb. centric loading condition without interference with the rearward movement of the sliding bogie. The condition shown represents the clearance available with our current production bogie setting at it's rearmost setting (64 inches). This, however, would represent an eight inch interference with equipment manufactured to a minimum setting of 56 inches which is the case with some manufacturers. (centerline of tandem to rear of trailer). Weight distributions for guards with equipment of this type would approach an equivalent to a rigid vertical guard as described earlier.

As in the case of the rigid vertical guard, additional structural reinforcement will be required. In this case, requirements exist to reinforce the floor structure and structural tie to the rear sill as shown in Figure 2-14 in order to react the upward load introduced by the strut.

Similarly, Figures 2-15 and 2-16 describe the configuration for the 50,000 lb. centric load with the strut supports projected into a 24 inch interference with the sliding bogie to cover the range of possibilities projected by the program work statement.

The weight results for this category are given in Figures 2-17 to 2-20 for the zero interference, 12 inch interference, and 24 inch interference, respectively. As can be seen by comparison of the results with zero interference through 24 inch interference, there is no weight advantage to projecting the struts into the interference area when considering the geometries presented herein.

Other geometries which utilize a maximum rearmost setting closer to the rear sill would, of course, not yield the same results. Figure 2-18 shows the offset loading condition results



RIGID GUARD STRUT SUPPORTED
NO INTERFERENCE SLIDING BOGIE CONFIGURATION
50,000 LB CENTRIC LOAD DESIGN

FIGURE 2-13

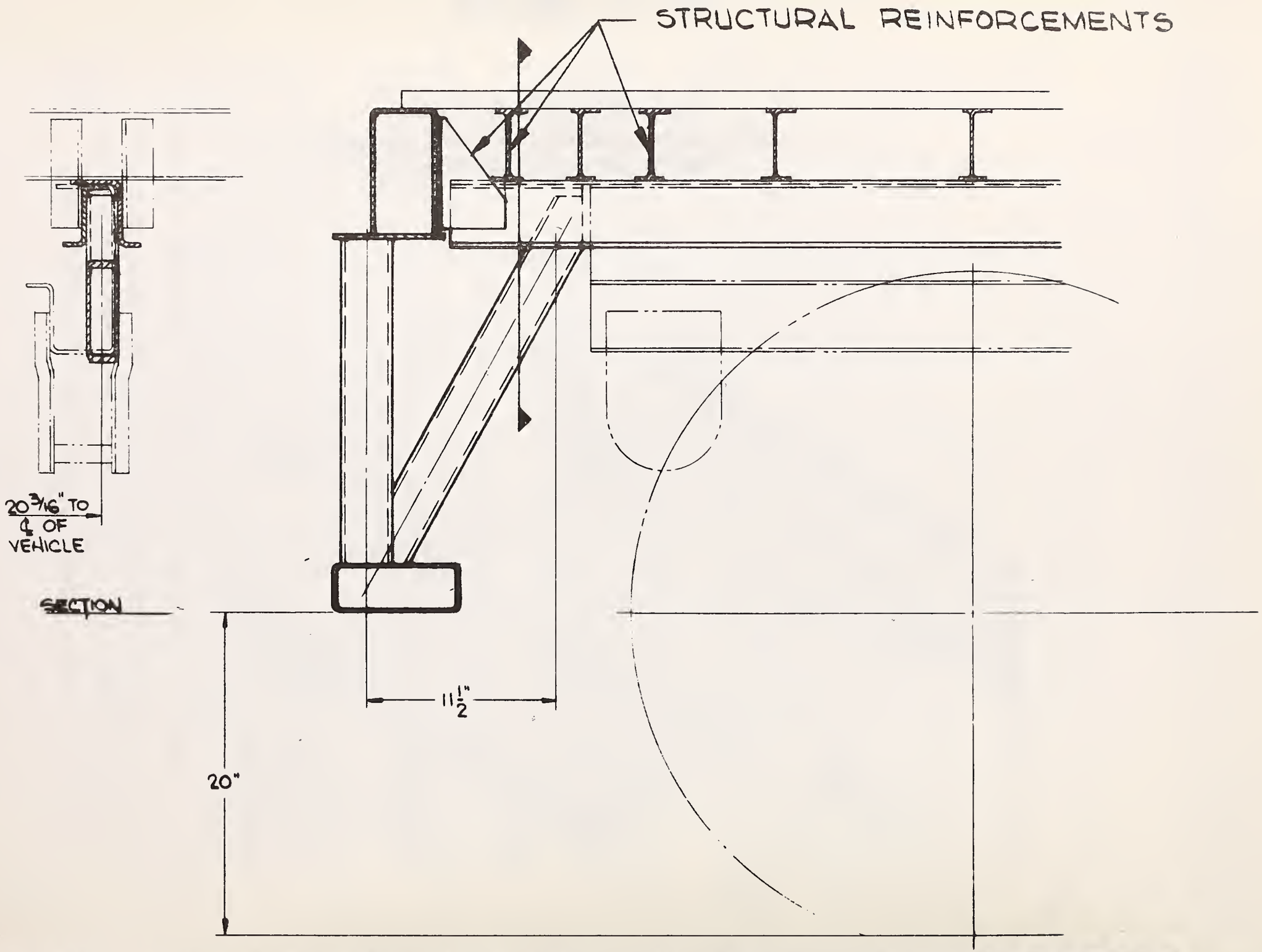
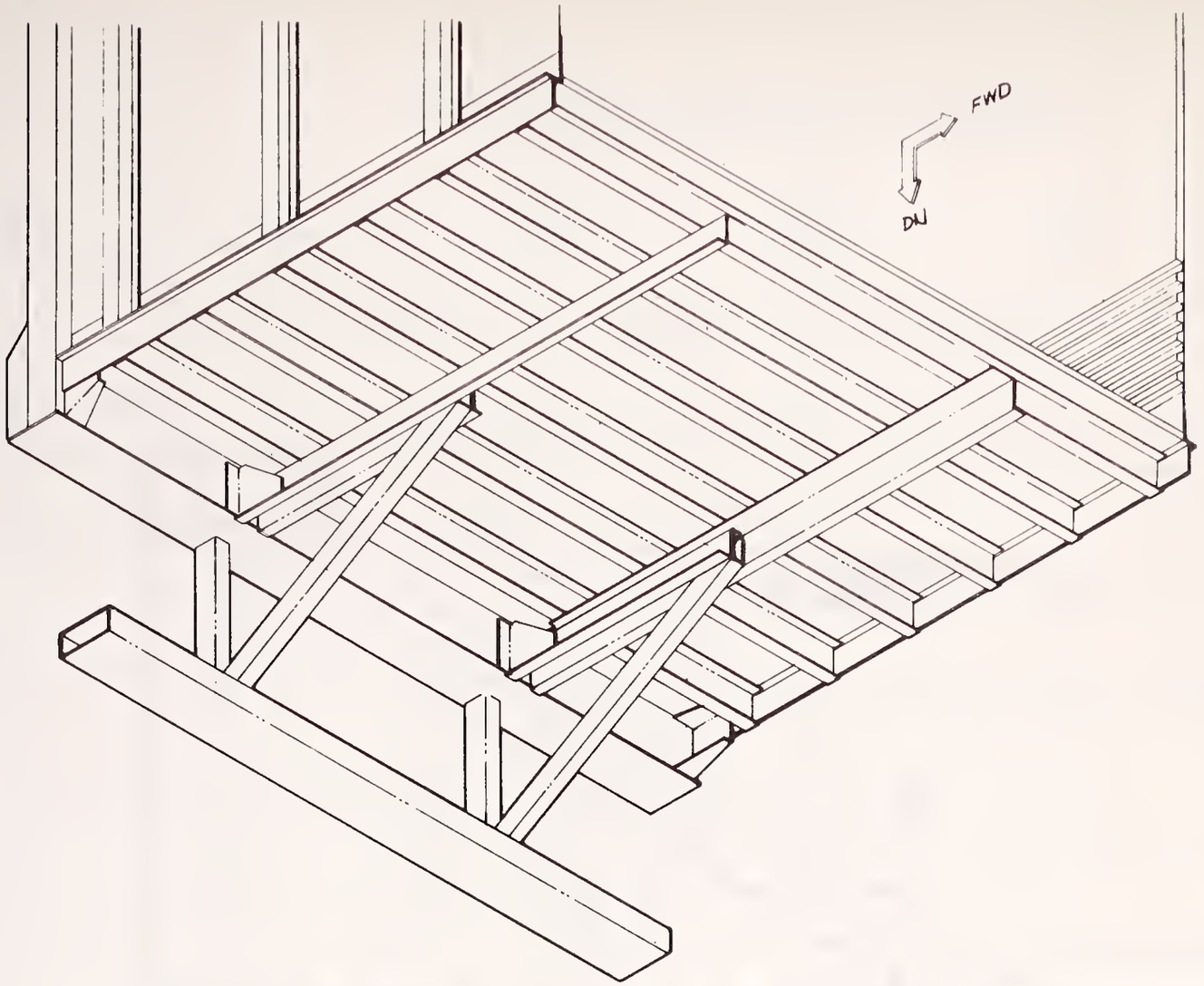


FIGURE 2-14 RIGID GUARD STRUT SUPPORTED SECTION VIEW NO INTERFERENCE



RIGID GUARD STRUT SUPPORTED
24" INTERFERENCE SLIDING BOGIE CONFIGURATION
50,000 LB CENTRIC LOAD DESIGN

FIGURE 2-15

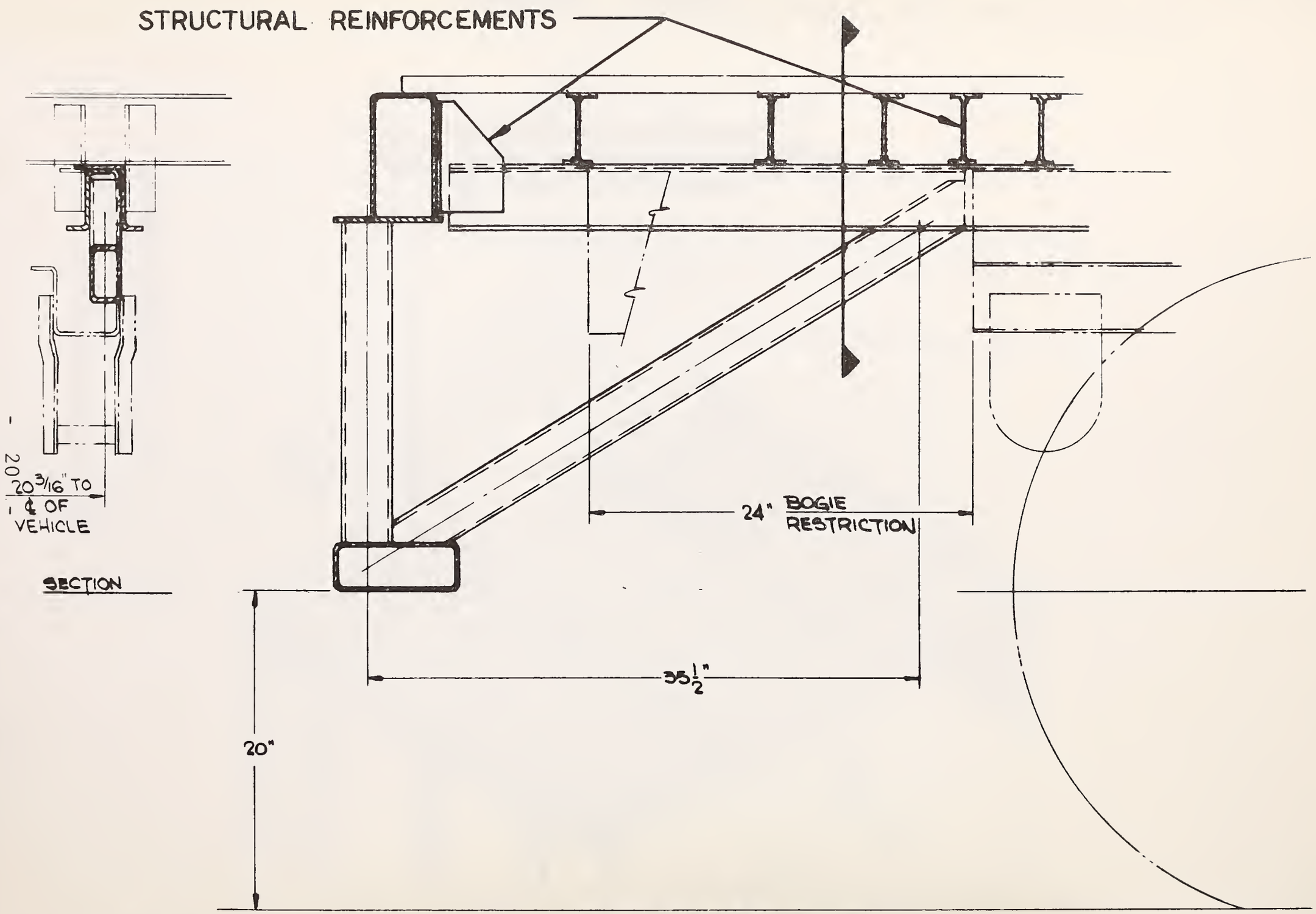


FIGURE 2-16 RIGID GUARD STRUT SUPPORTED SECTION VIEW 24" INTERFERENCE

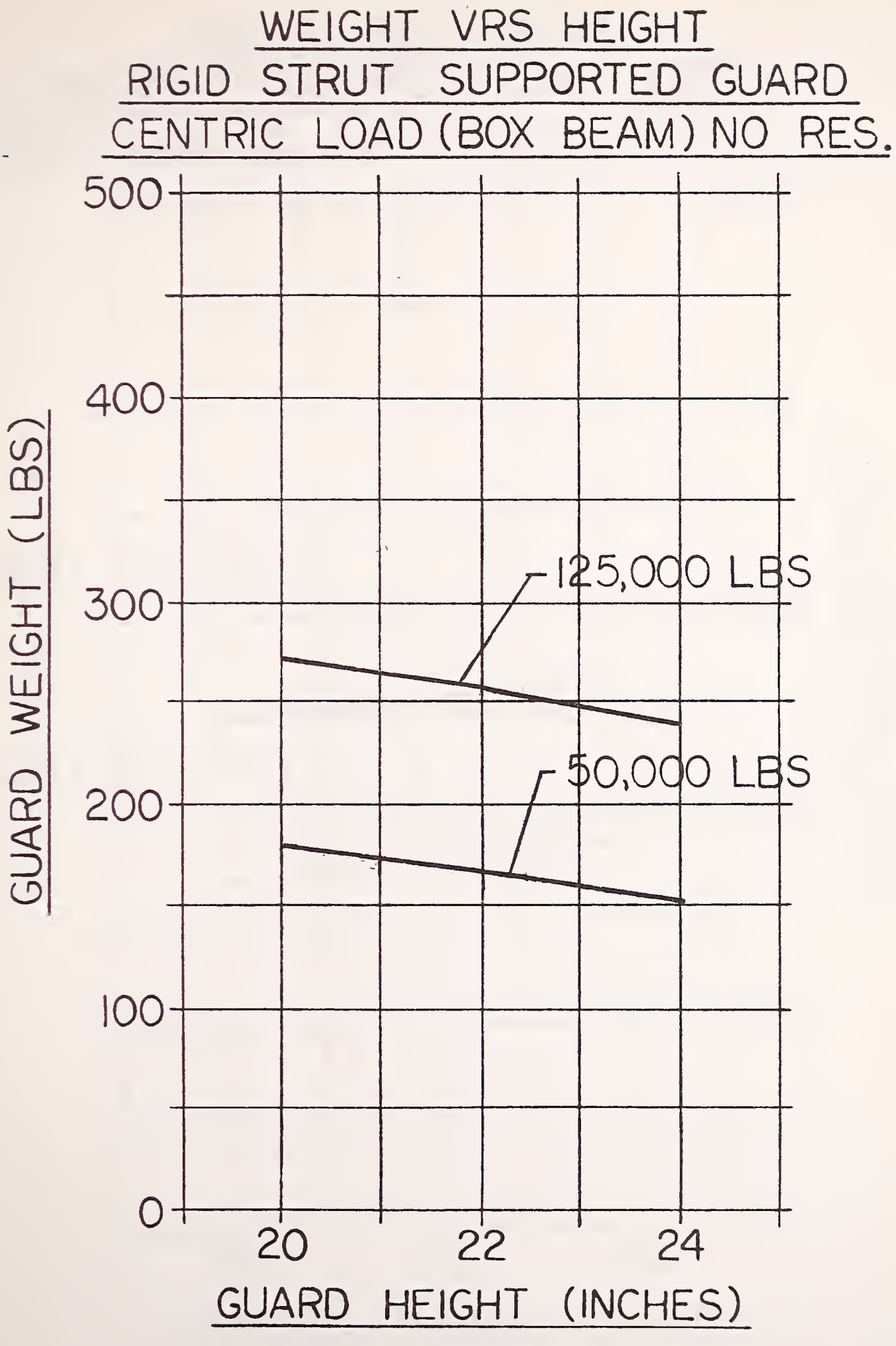

WEIGHT VRS HEIGHT
RIGID STRUT SUPPORTED GUARD
CENTRIC LOAD (BOX BEAM) NO RES.
GUARD WEIGHT (LBS)
500
400
300
200
100
0
125,000 LBS
50,000 LBS
20
22
24
GUARD HEIGHT (INCHES)

FIGURE 2-17

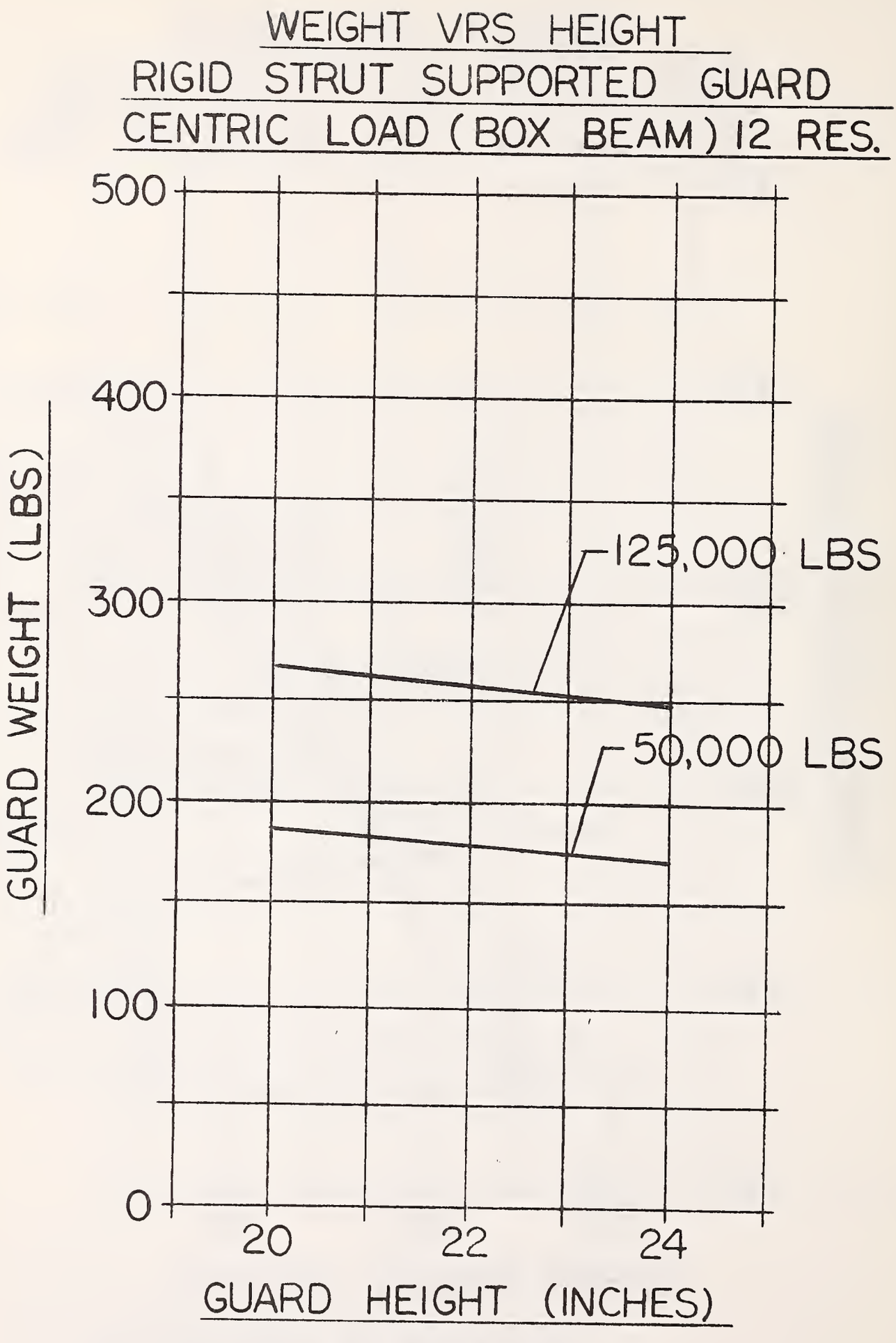

WEIGHT VRS HEIGHT
RIGID STRUT SUPPORTED GUARD
CENTRIC LOAD (BOX BEAM) 12 RES.
GUARD WEIGHT (LBS)
500
400
300
200
100
0
125,000 LBS
50,000 LBS
20
22
24
GUARD HEIGHT (INCHES)

FIGURE 2-18

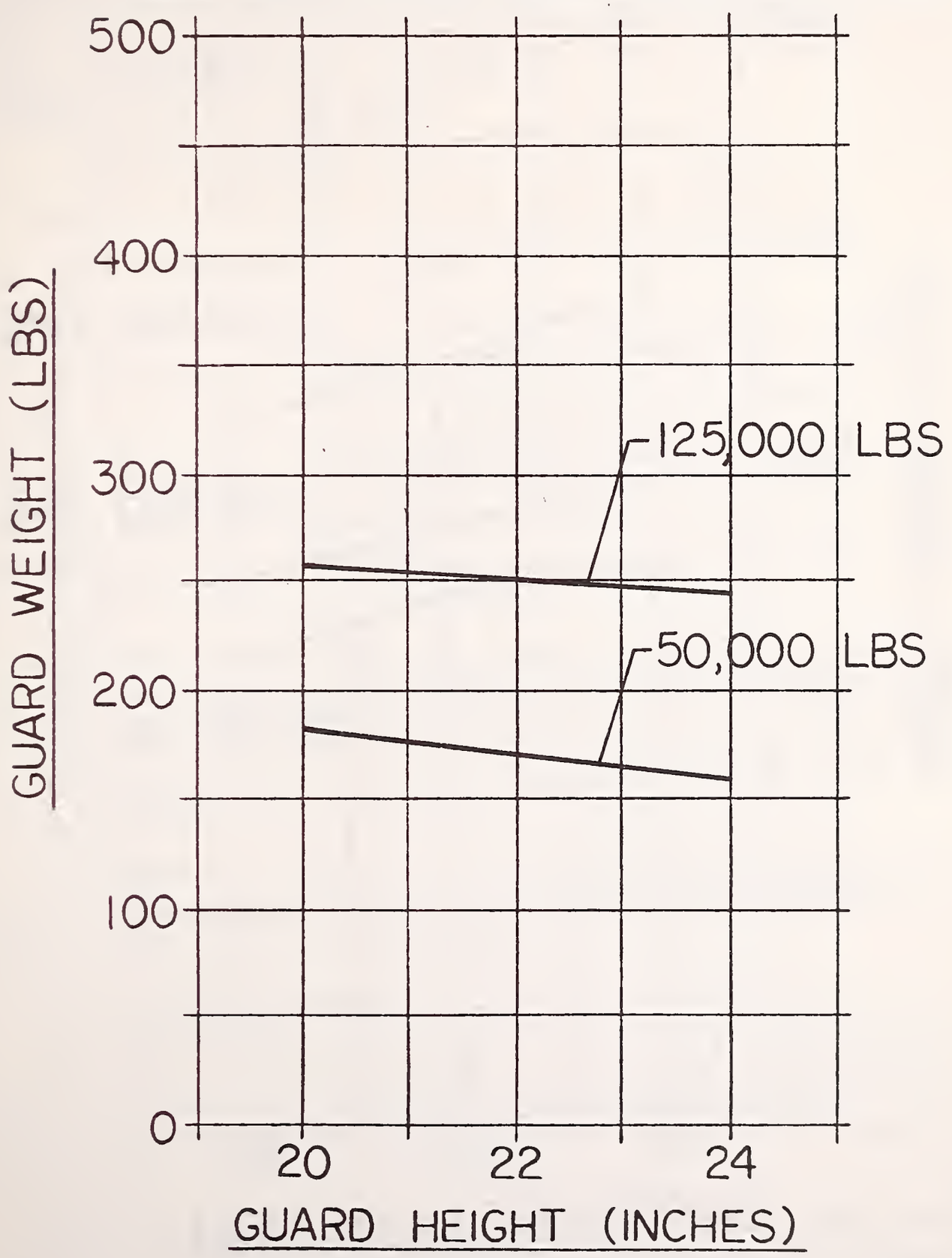

WEIGHT VRS HEIGHT
RIGID STRUT SUPPORTED GUARD
CENTRIC LOAD (BOX BEAM) 24" RES.
500
400
300
200
100
0
GUARD WEIGHT (LBS)
125,000 LBS
50,000 LBS
20
22
24
GUARD HEIGHT (INCHES)

FIGURE 2-19

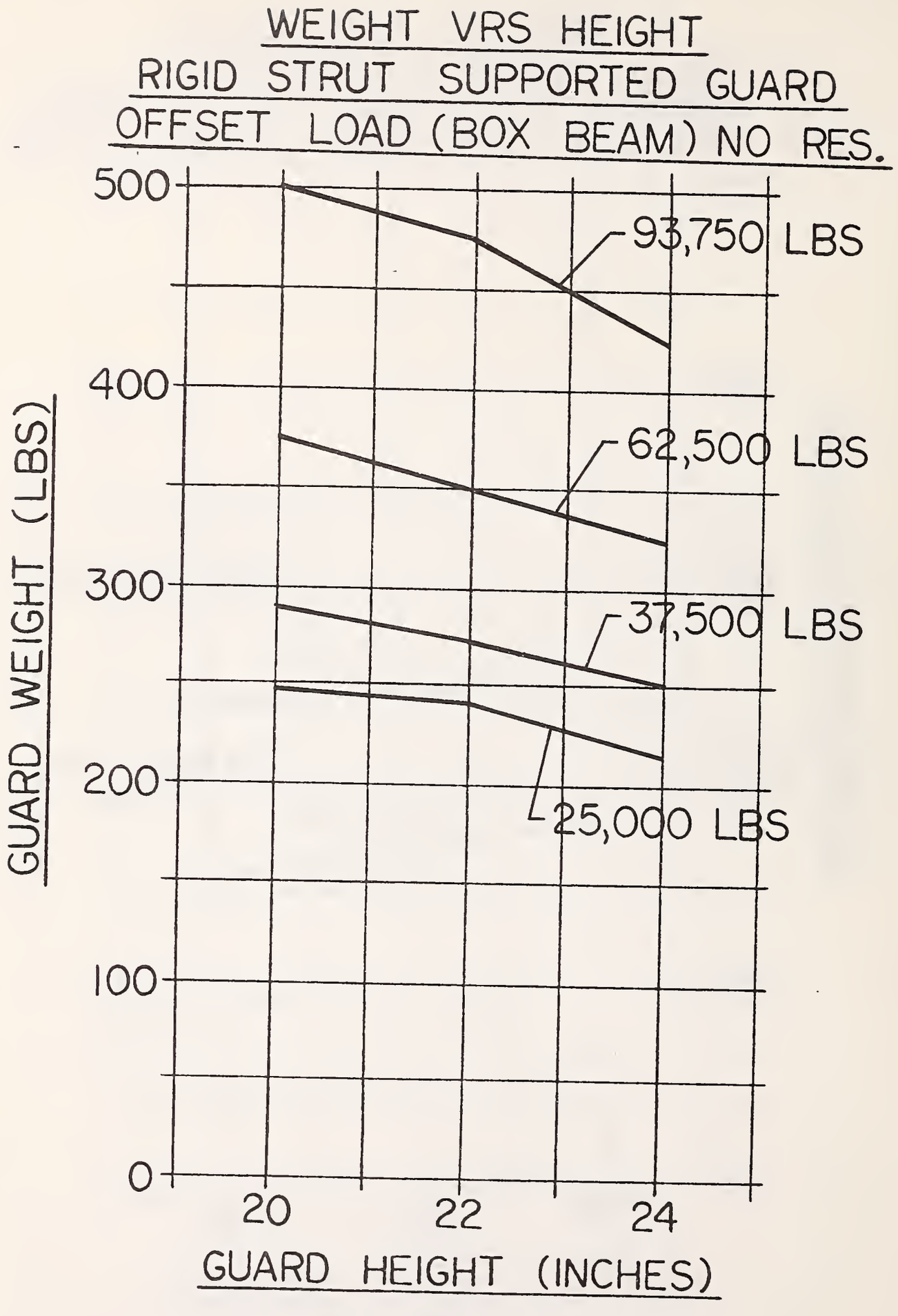

WEIGHT VRS HEIGHT
RIGID STRUT SUPPORTED GUARD
OFFSET LOAD (BOX BEAM) NO RES.
GUARD WEIGHT (LBS)
500
400
300
200
100
0
93,750 LBS
62,500 LBS
37,500 LBS
25,000 LBS
20
22
24
GUARD HEIGHT (INCHES)

FIGURE 2-20

for the zero interference case.

Utilizing the same reasoning for the strut supported configuration as that described earlier for the vertical guard with respect to box sections versus I-beams, a configuration was prepared with the I-beam approach. This is shown in Figure 2-21 sized for the 50,000 lb. centric loading condition. Once again the net result was slightly reduced weight as compared to the box beam as illustrated in the data given in Figure 2-22.

2.3 Rigid Offset Strut Supported Guard

The third configuration considered was a strut supported guard wherein the strut support point would be outboard of the bogie rail so as to provide no interference with movement. A concept which will accomplish this end is given in Figure 2-23. As shown in the figure and also in the sectional view of Figure 2-24, the member is supported to the outside of the slider rail 'A' member which is reinforced by the addition of an added stiffener shown.

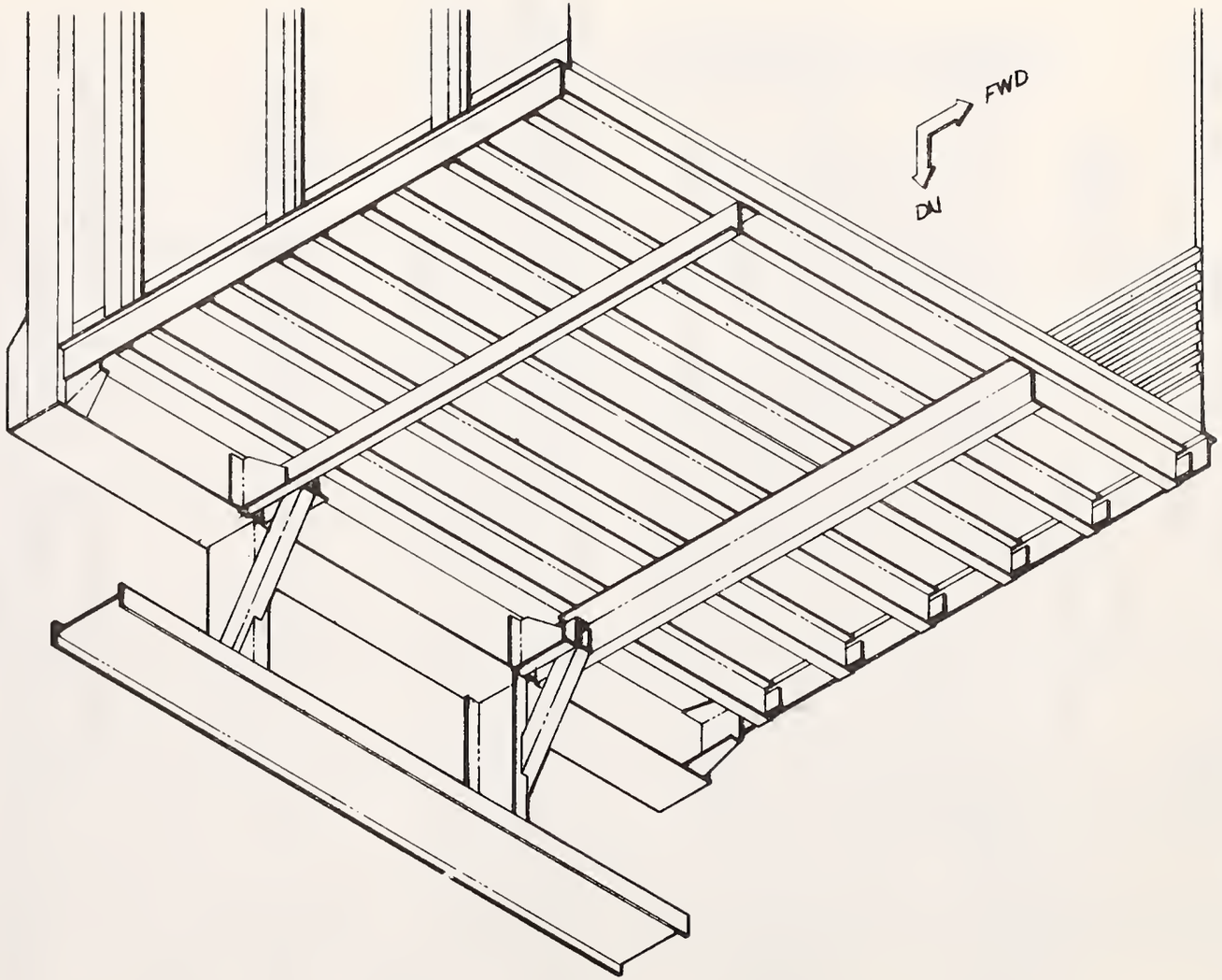
It should be noted that the added stiffener and support area with this configuration must be kept aft of the tires in the rearmost position to avoid possible interference. Tire clearances to structure should be maintained at 1 1/2 inch minimum in the full jounce position.

The weight distribution for this configuration is given in Figure 2-25 for the centric loading condition and the offset conditions are given in Figure 2-26.

2.4 Energy Absorbing Guard

The final and most promising design concept reviewed herein is one which would provide energy absorbing characteristics to allow the automobile and its occupants to ride down during the impact event.

Since no standard EA device is available, the design concept applied is one which utilizes experience of Budd in the design and development of crashworthy automobile structures. Automobile frontal frame elements have been developed to provide a controlled



RIGID GUARD STRUT SUPPORTED
NO INTERFERENCE SLIDING BOGIE CONFIGURATION
50,000 LB CENTRIC LOAD DESIGN

FIGURE 2-21

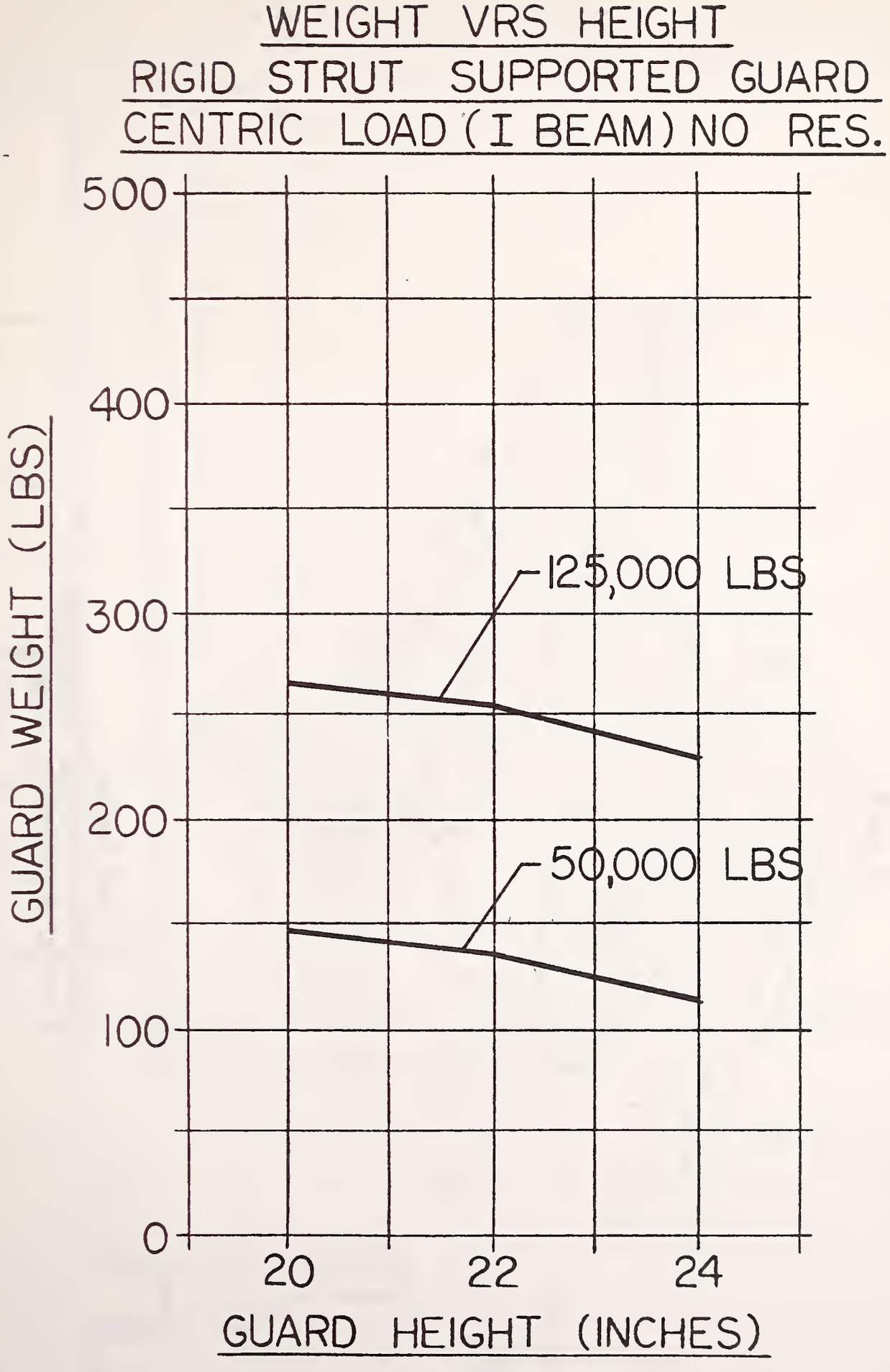
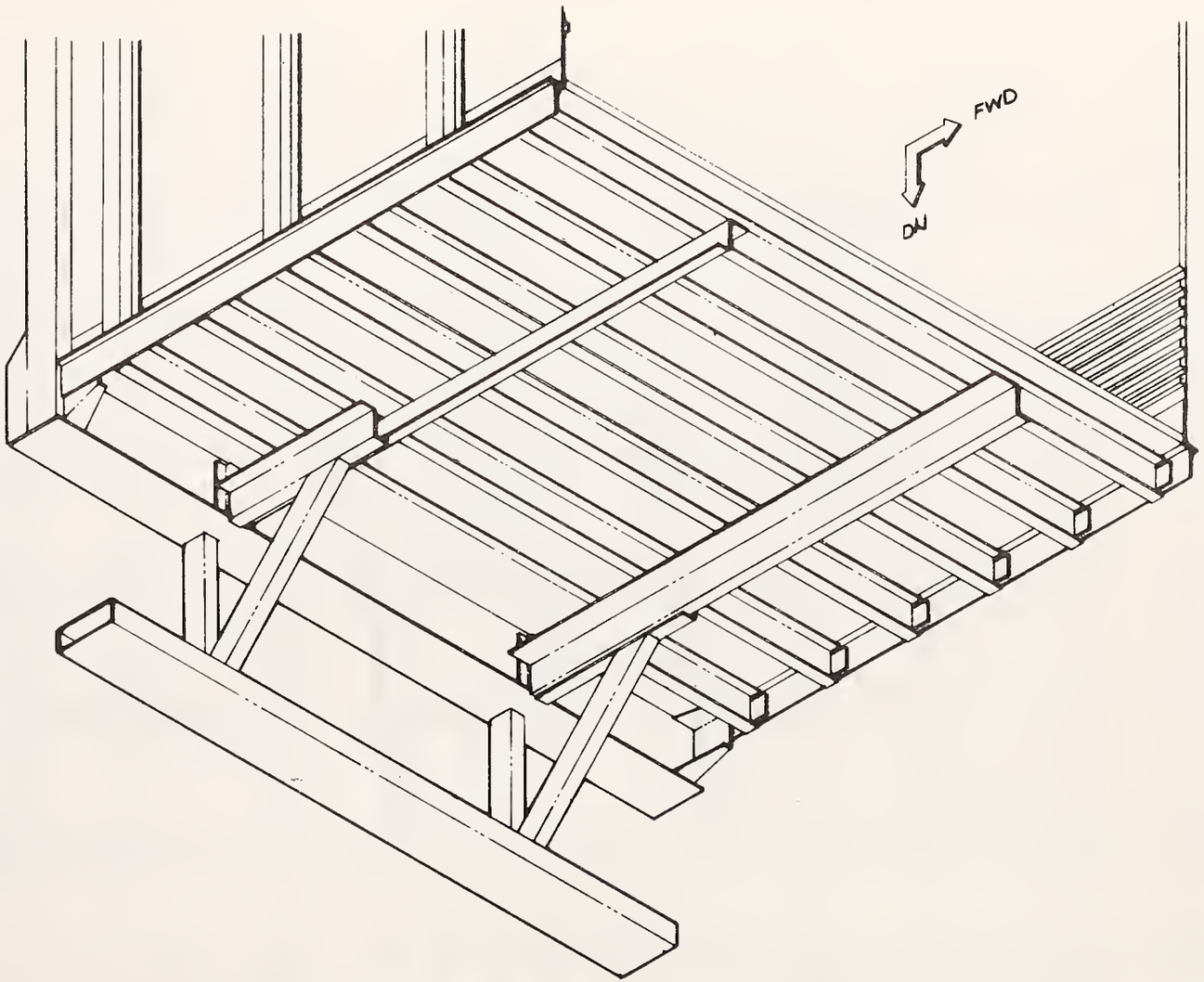

WEIGHT VRS HEIGHT
RIGID STRUT SUPPORTED GUARD
CENTRIC LOAD (I BEAM) NO RES.
GUARD WEIGHT (LBS)
500
400
300
200
100
0
125,000 LBS
50,000 LBS
20
22
24
GUARD HEIGHT (INCHES)

FIGURE 2-22



RIGID GUARD
OUTSIDE STRUT SUPPORTED CONFIGURATION
50,000 LB CENTRIC LOAD DESIGN

FIGURE 2-23

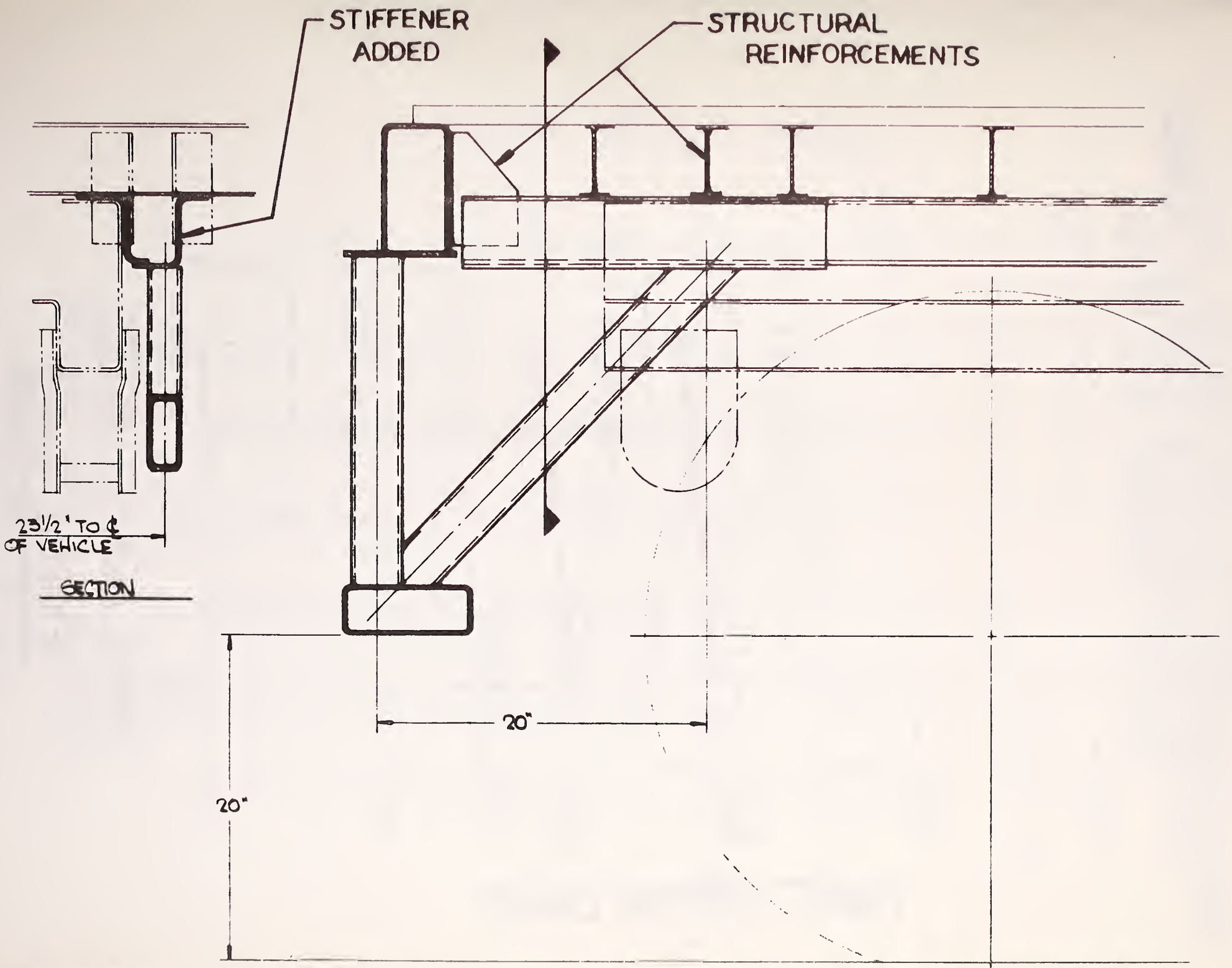


FIGURE 2-24 RIGID GUARD OUTSIDE STRUT SUPPORTED SECTION VIEW

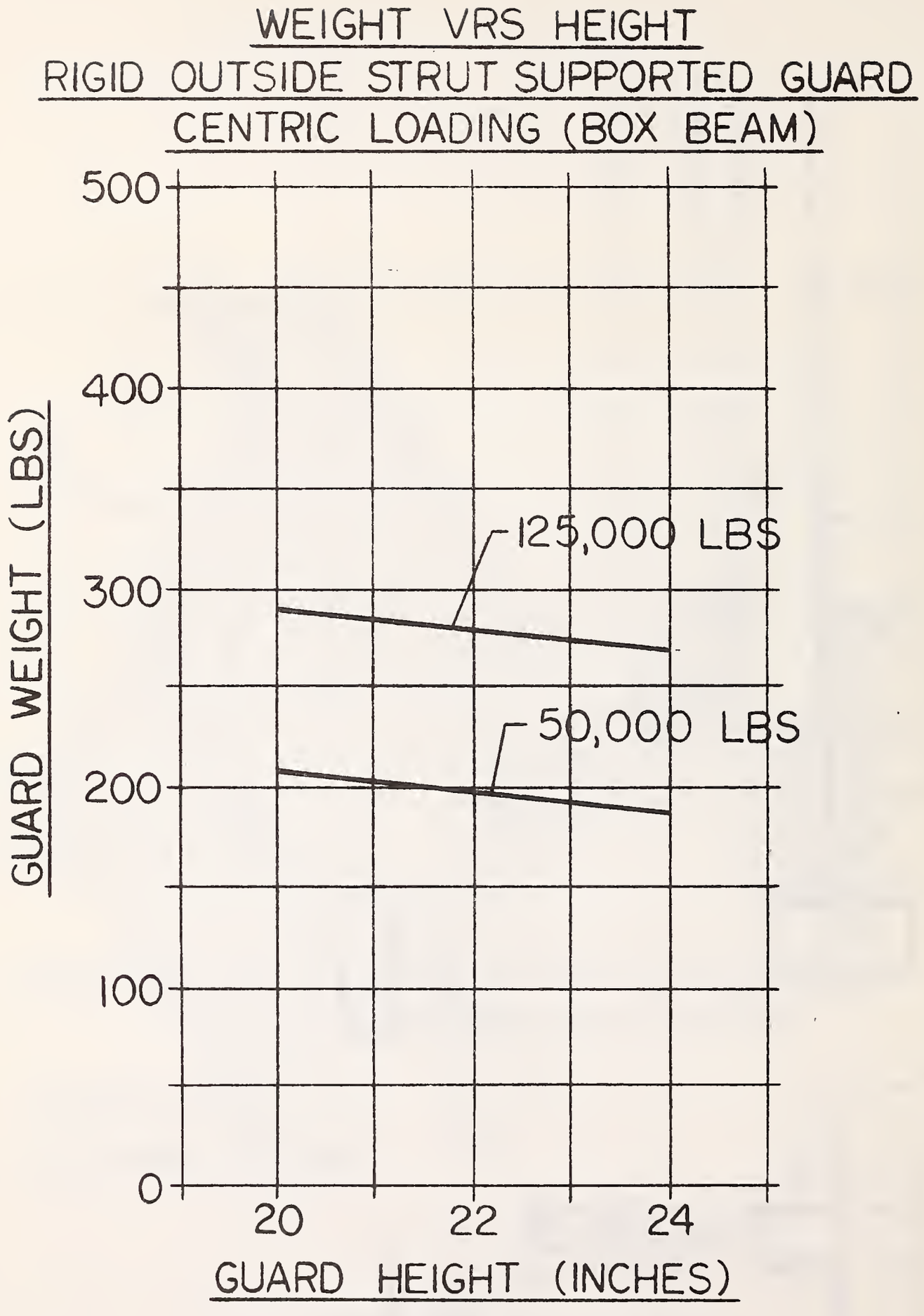

WEIGHT VRS HEIGHT
RIGID OUTSIDE STRUT SUPPORTED GUARD
CENTRIC LOADING (BOX BEAM)
500
400
300
200
100
0
GUARD WEIGHT (LBS)
125,000 LBS
50,000 LBS
20
22
24
GUARD HEIGHT (INCHES)

FIGURE 2-25

WEIGHT VRS HEIGHT
RIGID OUTSIDE STRUT SUPPORTED GUARD
OFFSET LOAD (BOX BEAM)

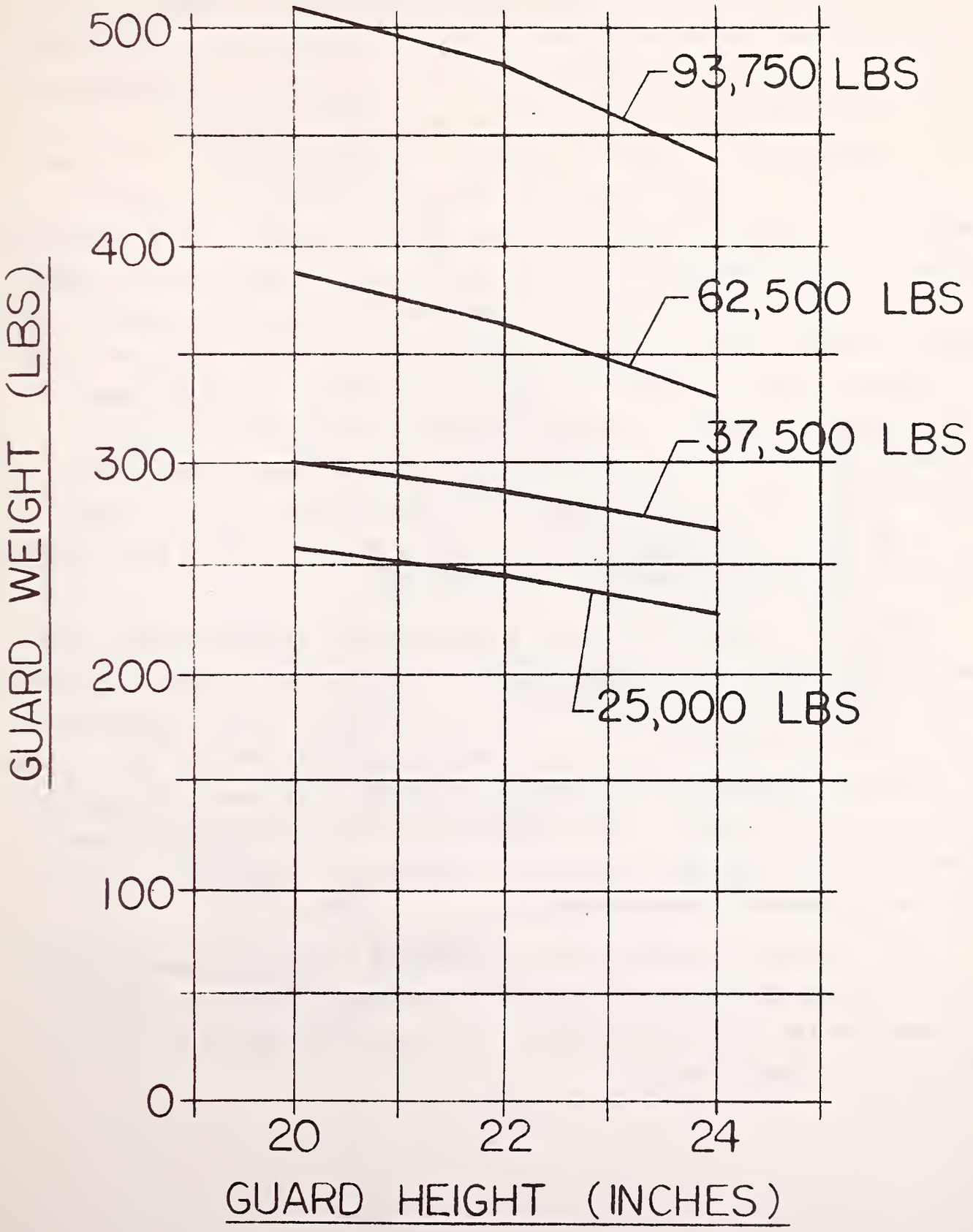


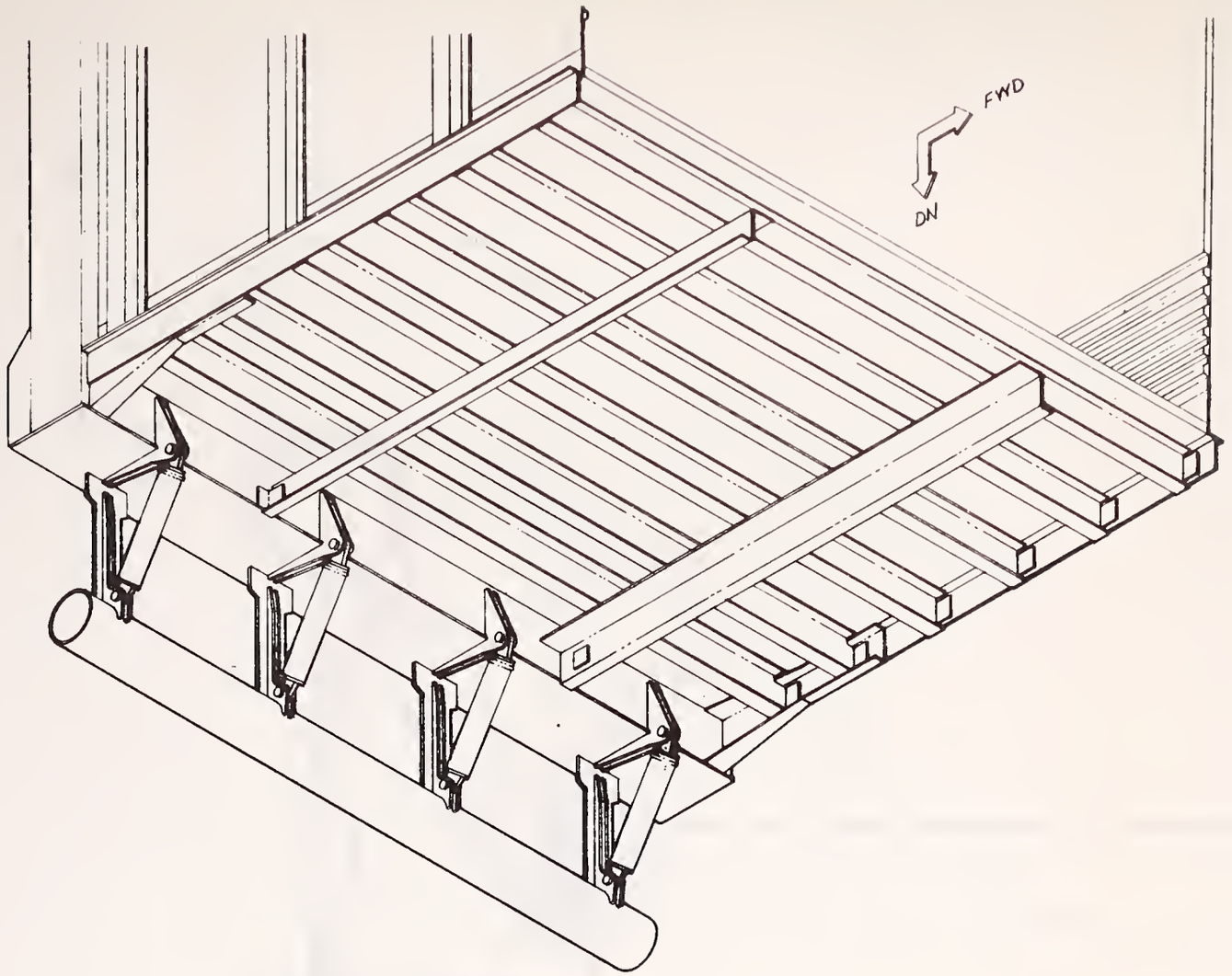
FIGURE 2-26

energy absorbing crush on impact and it is this concept which has been analysed for this application.

An illustration of such a device is given in Figure 2-27 and a sectional view in Figure 2-28. As shown in the sectional view, the rear strut elements are designed with a triggering device (pre-dimpled) to initiate a controlled crushing of the outer element for a linear distance of approximately 12 inches at which point a solid internal stop will bottom as shown to absorb the remaining energy in the vehicle impact. The vertical member will be designed to withstand normal minor docking loads but would deflect by bending on automobile impact as shown. Another possible variation of the concept is shown in Figure 2-29 with three strut supports as opposed to four. A preliminary approximate sizing of elements involved has yielded a weight estimate for the device of 225 lbs. for the three strut version and 270 lbs. for the four strut configuration. This is based on a system to provide a stroking force in the 50,000 to 60,000 lb. area and a bottoming force of 100,000 lbs.

While the effect of these forces on the trailer structure has not been fully analyzed, we estimate that additional structural reinforcing equivalent to 50 to 75 lbs. will be required. This is quite dependent on the impacting vehicle mass and velocity and the interaction of energy absorption between the vehicle and the trailer guard. The magnitude of the remaining energy after the stroking will ultimately determine the trailer structure reinforcement requirements.

As a trailer manufacturer as well as the developer of this type of automotive energy absorber structure, The Budd Company is considering developing this and similar concepts as a product for this application.



ENERGY ABSORBING GUARD
4 STRUT CONFIGURATION

FIGURE 2-27

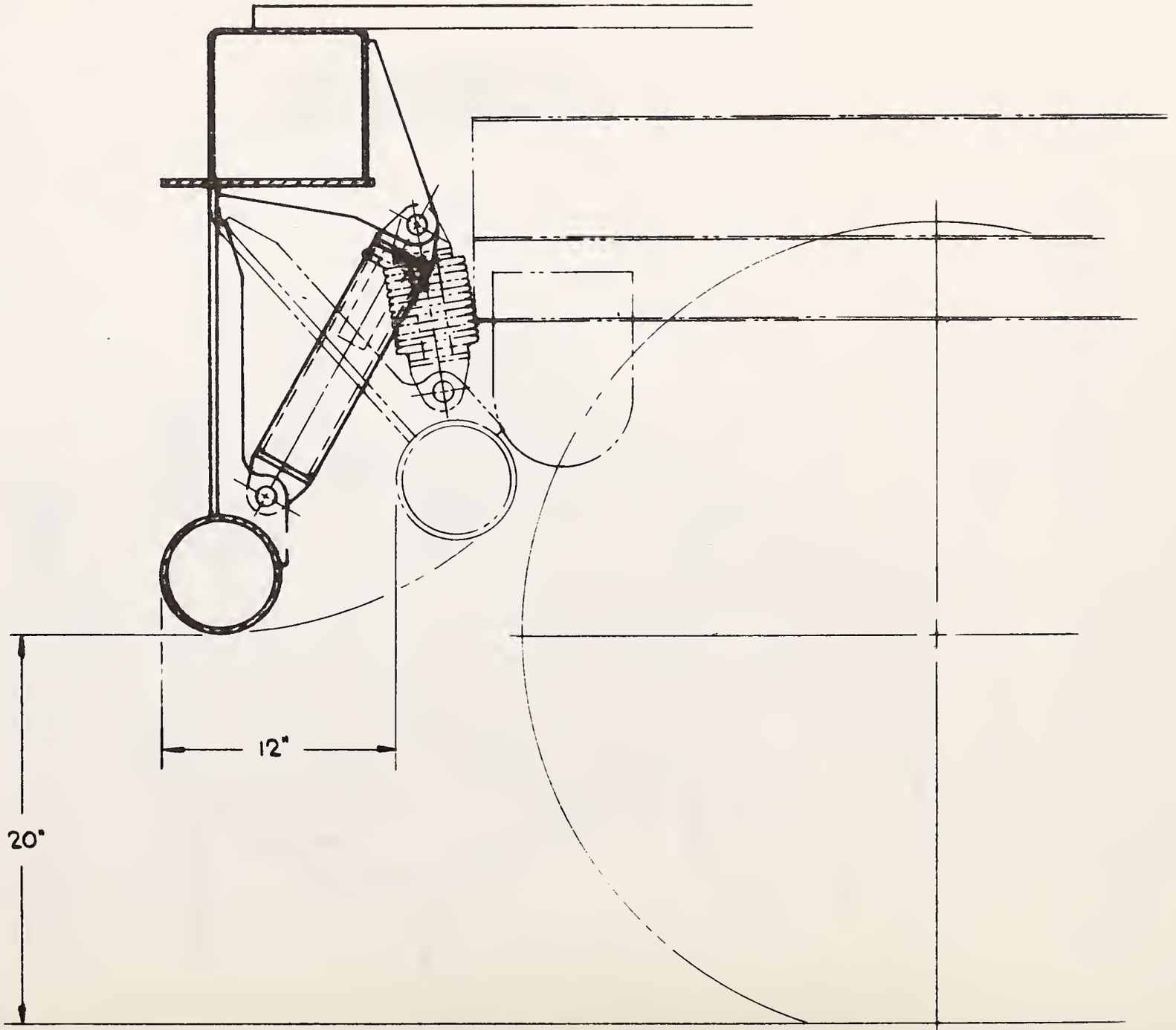
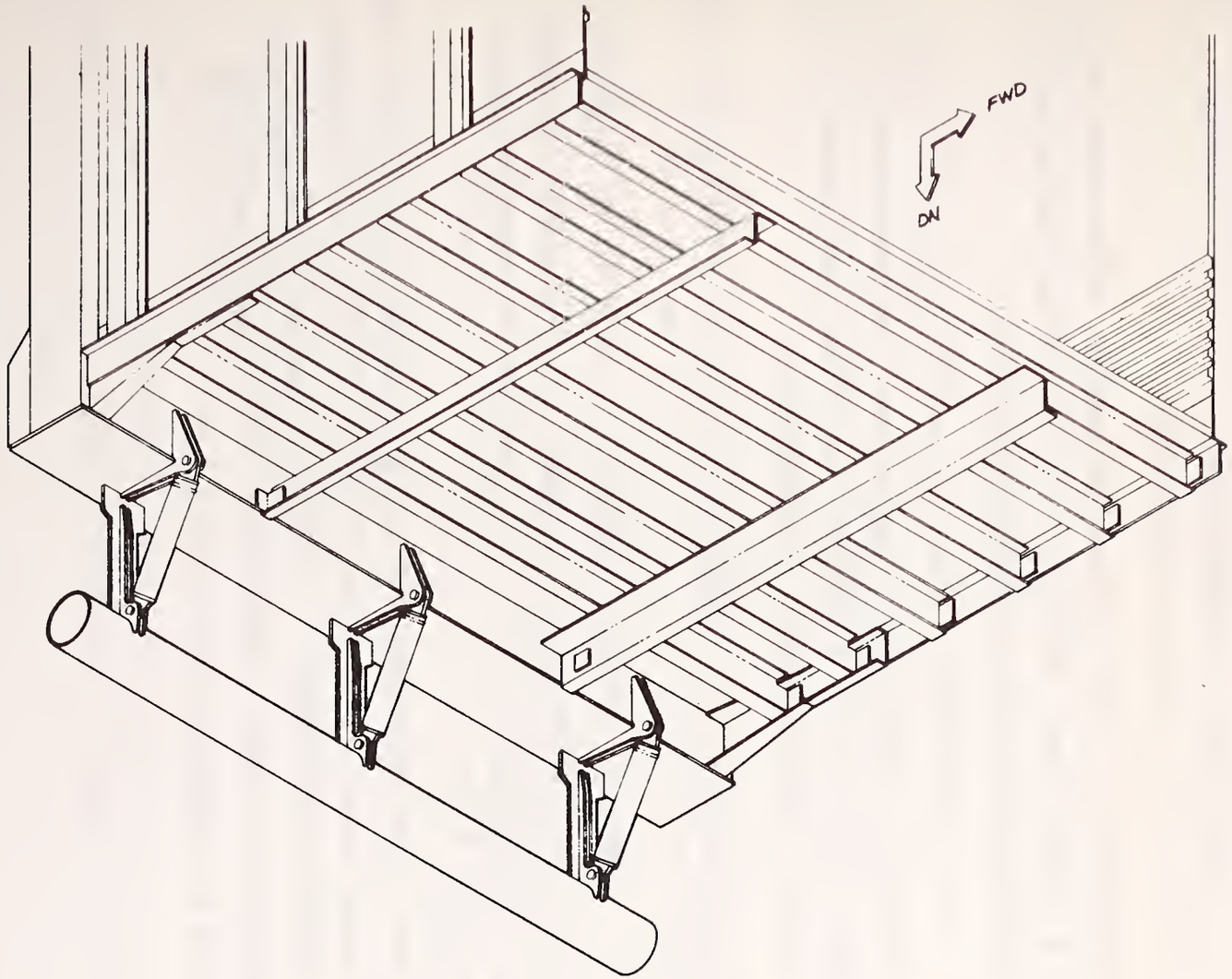


FIGURE 2-28 ENERGY ABSORBING GUARD SECTION VIEW



ENERGY ABSORBING GUARD
3 STRUT CONFIGURATION

FIGURE 2-29

3.0 CONCLUSIONS

Based on the study described herein, the following conclusions are drawn:

1. The effect of adding structural reinforcements to the trailer structures to sustain the loading levels analyzed herein is a major cost implication and consideration.

2. The design approach of those analyzed which offers the most promise for a weight/cost effective solution to the underride guard problem is the energy absorbing guard.

3. In order to accurately define the degree of structural reinforcement required, a detailed system load response analysis of a much more sophisticated nature than that performed within the limitations of this study is necessary.

4. The heaviest and most costly approach of those reviewed is the rigid vertical guard.

5. With the strut supported guard approach, there is no apparent major weight or cost advantage in restricting slider movement beyond the 64 inch setting (rear of trailer to centerline of tandem) discussed herein.

6. The trailer structures currently being manufactured by The Budd Company and many others are significantly lighter in construction than the Fruehauf model previously tested and suggested for consideration in this study. As such, the reinforcing required would be substantially different.

4.0 RECOMMENDATIONS

The following recommendations are offered for your consideration:

1. A more detailed analysis of the trailer structure response and required reinforcement is recommended including finite element techniques in order to provide more accurate definition.

2. A mass model analysis similar to that developed by NHTSA and employed by The Budd Company in the development of automobile crashworthiness is suggested to determine the interaction between the vehicles in the crash event.

3. The degree and nature of damage which would be sustained by plastic deformations within the trailer structure and their effect on the vehicle should be investigated.

4. The effectiveness and weight of energy absorbing guards should be further analyzed and developed to verify their apparent relative advantages versus rigid designs.

5. A program of scale model and full scale testing should be undertaken in combination with the analytical work. Scale model testing can be utilized in a more economical and timely fashion as opposed to full scale testing to establish dynamic plastic deformation effects, design modification effectiveness, vehicle energy interaction, energy absorber efficiencies, and overall guard design performance with varying impact velocities and attitudes.

Background information on scale modelling techniques as employed by The Budd Company Technical Center are shown in Appendix 'B' of this report.

APPENDIX A

Weight Tabulations

NOTES:

1. The tables following represent a detailed breakdown of the component member and modification weights for each of the underride guard design configurations analyzed.

2. All design I-beam and box sections were selected to be standard commercially available shapes.

3. All material utilized in the design was H.S.L.A. steel in the 45-50 ksi yield strength range which was selected to be consistent with the one dollar per pound manufacturing cost estimate for standard construction.

4. Standard classical bending and buckling criteria analysis techniques were used throughout for sizing.

TABLE LEGEND

P	=	LOAD IN LBS X 1000
CLEAR	=	GROUND CLEARANCE IN INCHES
VERT	=	WEIGHT OF EACH VERTICAL MEMBER IN LBS
DIAG	=	WEIGHT OF EACH DIAGONAL MEMBER IN LBS
HORIZ	=	WEIGHT OF THE HORIZONTAL BEAM IN LBS
V. MOD	=	VEHICLE MODIFICATION WEIGHT IN LBS
TOTAL	=	TOTAL WEIGHT IN LBS

STRUT CONFIGURATIONS ALL BOX
CENTRIC LOADING

P	CLEAR	VERT.	DIAG.	HORIZ.	V. MOD.	TOTAL
0" TRAVEL RES.						
50	20	6.8	8.4	91.91	50	172.31
	22	6.1	7.8		42.5	162.21
	24	5.4	7.2		35	152.11
125	20	10.9	17.2	135.87	75	267.07
	22	9.5	15.1		70	255.07
	24	6.86	12.8		65	240.19
12" TRAVEL RES.						
50	20	7.36	11.2	91.91	50	179.03
	22	6.64	10.74		42.5	169.17
	24	5.93	10.31		35	159.39
125	20	6.82	17.28	135.87	75	259.07
	22	6.11	16.58		70	251.25
	24	5.39	15.94		65	243.53
24" TRAVEL RES.						
50	20	6.8	14.7	91.91	45	179.91
	22	6.1	14.4		37.5	170.41
	24	5.4	14.1		30	160.91
125	20	5.7	23	135.87	60	253.27
	22	5	22.5		55	245.87
	24	4.31	22		50	212.18

STRUT CONFIGURATIONS ALLBOX
OFFSET LOADING

OFFSET 50%

0" TRAVEL RES.

P	CLEAR	VERT.	DIAG.	HORIZ.	V. MOD.	TOTAL
25	20	8.1	13.2	131.74	70	244.34
	22	7.2	12.2		65	235.54
	24	5	8.9		60	219.54
62.5	20	15.8	27	201.81	85	372.41
	22	12	24.8		75	350.41
	24	10.5	18.9		65	325.61
12" TRAVEL RES.						
25	20	6.5	14.6	131.74	65	238.94
	22	5.7	14.3		55	226.74
	24	5	14		45	214.74
62.5	20	5.7	29.5	201.81	80	352.21
	22	5	28.9		70	339.61
	24	4.31	28.2		60	326.83

OFFSET 75%

0" TRAVEL RES.						
37.5	20	11.7	16.3	135.87	85	276.87
	22	8	15.1		80	262.07
	24	6.9	13.9		75	252.47
93.75	20	19.6	37.2	278.18	110	501.78
	22	15.4	30.8		100	470.58
	24	12.1	25.4		90	443.18
24" TRAVEL RES.						
37.5	20	5.7	23	135.87	80	273.27
	22	5	17.7		75	256.27
	24	4.3	17.3		70	249.07
93.75	20	6.3	48.2	278.18	100	487.18
	22	5.4	39		90	456.98
	24	3.6	37.7		80	440.78

STRUT HORIZ. I DIAG. BOX

CENTRIC LOADING

0" TRAVEL RES.

P	CLEAR	VERT.	DIAG.	HORIZ.	V. MOD.	TOTAL
50	20	7.4	10.3	63	50	148.4
	22	6.7	7.6		42.5	134.1
	24	4.5	7		35	121
125	20	19.3	20.4	115.5	75	269.9
	22	17.4	16.5		70	253.3
	24	10.9	14.6		65	231.5
24" TRAVEL RES.						
50	20	2.6	14.3	63	45	141.8
	22	2.4	13.9		37.5	133.1
	24	2.1	13.6		30	124.4
125	20	5.4	22.5	115.5	60	231.3
	22	4.1	22		55	222.7
	24	2.9	21.4		50	214.1

OFFSET 50%

0" TRAVEL RES.						
25	20	11.8	12.8	80.5	70	199.7
	22	8	11.8		65	185.1
	24	7.1	10.8		60	176.3
62.5	20	23.5	31.4	154	85	348.8
	22	21.2	24.9		75	321.2
	24	18.8	22.8		65	302.2
24" TRAVEL RES.						
25	20	5.9	14.2	80.5	65	185.7
	22	5.3	13.8		55	173.7
	24	4.7	13.5		45	161.9
2.5	20	7.4	28.9	154	80	306.6
	22	6.7	28.2		70	293.8
	24	4.7	27.6		60	278.6

STRUT HORIZ. I DIAG. BOX

OFFSET 75% LOADING

0" TRAVEL RES.

P	CLEAR	VERT.	DIAG.	HORIZ.	V. MOD.	TOTAL
37.5	20	17.3	19.6	98	85	256.8
	22	15.6	16		80	241.2
	24	9.4	12.8		75	217.4
93.75	20	41.3	41.6	182	110	457.8
	22	28.6	36.5		100	412.2
	24	25.3	31.7		90	386

24" TRAVEL RES.

37.5	20	5.9	22.6	98	80	235
	22	5.3	22		75	227.6
	24	4.8	16.9		70	211.4
93.75	20	11.3	47.3	182	100	399.2
	22	10.1	46.1		90	384.4
	24	6.7	37.3		80	350

CANTILEVER - BOX VERT "I"
HORIZONTAL CENTRIC LOADING

P	CLEAR	VERT.	HORIZ.	V. MOD.	TOTAL
50	20	28.4	63	0	119.8
	22	25.6		0	114.2
	24	22.8		0	108.6
75	20	34.9	80.5	53	203.3
	22	27.9		45	181.3
	24	24.6		37	166.7
100	20	46.4	98	106	296.8
	22	31.6		98	259.2
	24	31.6		90	251.2
125	20	51.4	115.5	160	378.3
	22	41.5		152	350.5
	24	36.7		144	332.9
		OFFSET - 50%			
25	20	34.95	80.5	0	150.4
	22	27.88		0	136.26
	24	27.88		0	136.26
37.5	20	46.42	98	53	243.84
	22	41.62		45	226.2r
	24	25		37	185
50	20	63.46	133	106	365.92
	22	46.1		98	323.2
	24	40.7		90	304.4
62.5	20	75.16	154	160	464.32
	22	56.84		152	419.68
	24	50.2		144	398.4

CANTILEVER - ALL BOX

OFFSET 75% LOADING

P	CLEAR	VERT.	HORIZ.	V. MOD.	TOTAL
37.5	20	38.44	135.87	0	212.75
	22	33.64		0	203.15
	24	21.96		0	179.79
56.25	20	55.91	201.81	53	366.63
	22	37.58		45	321.97
	24	32.23		37	303.27
75	20	54.88	225.61	106	441.37
	22	47.03		98	417.67
	24	33.12		90	381.85
93.75	20	71.13	278.18	160	580.44
	22	60.95		152	552.08
	24	39.19		144	500.56

CANTILEVER - ALL BOX

CENTRIC LOADING

P	CLEAR	VERT.	HORIZ.	V. MOD.	TOTAL
50	20	26.68	91.91	0	145.27
	22	23.87		0	139.65
	24	21.06		0	134.03
75	20	32.94	117.95	53	236.83
	22	25.88		45	214.71
	24	22.65		37	200.25
100	20	38.44	135.87	106	318.75
	22	25.62		98	285.11
	24	21.96		90	269.79
125	20	42.97	135.87	160	381.81
	22	25.62		152	339.11
	24	25.62		144	331.11
			OFFSET 50%		
25	20	32.94	131.74	0	197.62
	22	25.88		0	183.5
	24	22.65		0	177.04
37.5	20	38.44	135.87	53	265.75
	22	33.64		45	248.15
	24	21.96		37	216.79
50	20	55.91	153.72	106	371.54
	22	37.58		98	326.88
	24	28.83		90	301.38
62.5	20	62.71	201.81	160	487.23
	22	48.93		152	451.67
	24	32.23		144	410.27

CANTILEVER BOX VERTICAL I HORIZ.

OFFSET 75% LOADING

P	CLEAR	VERT	HORIZ.	V. MOD.	TOTAL
37.5	20	46.42	98	0	190.84
	22	41.62		0	181.24
	24	25		0	148
56.25	20	63.46	154	53	333.92
	22	56.84		45	312.68
	24	40.7		37	272.4
75	20	95.21	154	106	450.42
	22	65.5		98	383
	24	48.59		90	341.18
94.75	20	115.7	182	160	573.4
	22	84.83		152	503.66
	24	74.69		144	475.38

APPENDIX B

SCALE MODEL TESTING

The use of scale model testing for the development of crashworthy structures has been very successfully utilized by The Budd Company Technical Center over the past years on a wide variety of applications. One of the main advantages to performing crash testing in scale is the ability to obtain the required engineering data on performance at a significantly reduced cost as opposed to full scale testing. This is particularly true where the application calls for the development of a new structure or a dramatically revised one and where production tooling is not available to produce the full scale test specimen.

Examples of projects which have fallen into this category in the past include the development of the crashworthy structure for the General Motors 'X' body, the development of the all plastic crashworthy structure for the Department of Energy's near term electric vehicle, energy absorbing automobile frame developments for the Ford Motor Company and American Motor's products and others.

A key advantage to testing in scale is the ability to obtain a great deal of basic information and understanding of the mechanism involved in the modes of energy absorption within the structures and those factors which influence the mechanism. It is possible to break down structures into their component elements for individual test and by so doing obtain the most desirable characteristics from each such as crush rates, strength, and weight.

Modifications in design such as material types, gauges, and geometry can be made rapidly and subjected to evaluation without major expense.

The facility employed for the testing at The Budd Company Technical Center is shown in Figure 1B. The vertical drop tower is capable of testing specimens of 1/2 scale automobile structures or 3/8 scale trailer structures weighing over 1000 lbs. The facility is fully instrumented to obtain all of the

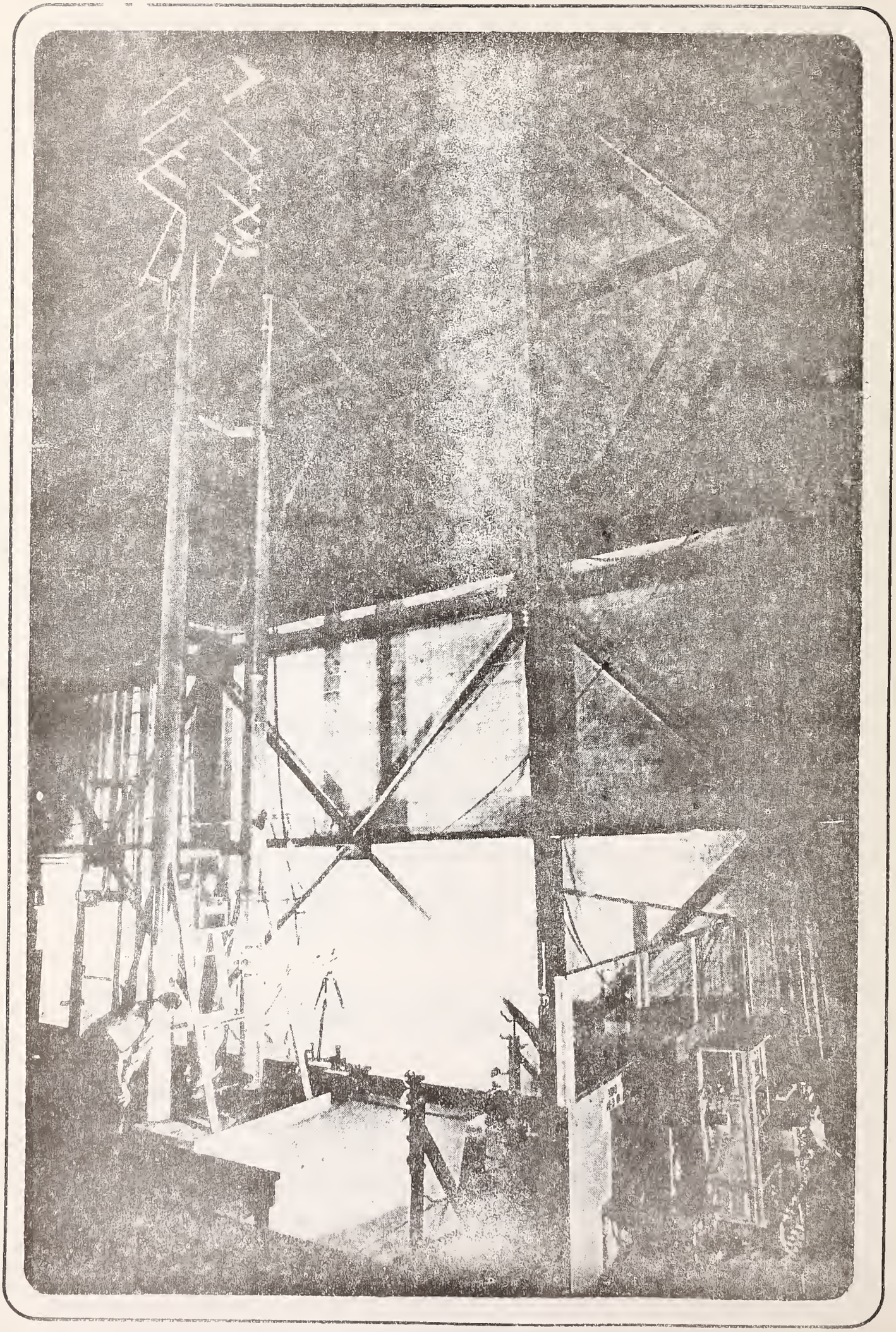


Figure 1B Drop Tower Facility

desired engineering information required such as impact velocity, impact loads, speed, acceleration, strain, as well as high speed motion picture recordings of the events for analysis.

Along with the development of the facility, The Budd Company has also obtained and developed over the years the associated scaling laws which make the technology viable. It is now possible and practical to predict accurately full scale performance in all engineering materials, metals as well as plastics, as has been demonstrated on many of the projects previously discussed.

One of the phenomena observed and documented on previous programs which is particularly applicable to the underride guard design is the increase in material yield strength under dynamic loading conditions, i.e. the crash event, as compared to normal static design limitations.

It is with this background in mind that it is suggested that the definitization of the basic elements of the trailer underride guard and its effect on the trailer structure could be economically established by the use of this technology. The type of program envisioned would be one which would establish through scale modelling:

1.) The dynamic response of a variety of guard devices, both rigid and energy absorbing type.
2.) The level or degree to which the various rear trailer structures can withstand the impact energy.
3.) The effect of plastic deformation within the guard and the structure on the crash event and vehicle passengers.
4.) The efficiency of modifications to the trailer structure and/or guard devices.

A program such as outlined could establish, in a much more positive manner, the overall effect of contemplated legislation on the design and manufacturing of the trailer structures. As a

final note regarding economics of this technology, our automotive customers have experienced savings wherein the scale model program would typically reduce costs to 25% of the full scale development investment level.

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Underride g
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